

Resource International, Inc.

**HAM-75-7.85
RETAINING WALL U
PID NO. 77889
HAMILTON COUNTY, OHIO**

**DRAFT STRUCTURE
FOUNDATION EXPLORATION
REPORT**

Prepared For:
**EMH&T
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Rii Project No. B-10-020

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May 25, 2012 (Revised August 8, 2013)

Mr. Edward D. Kagel, P.E.
Director of Transportation
EMH&T
5500 New Albany Road
Columbus, Ohio 43054

**Re: Draft Structure Foundation Exploration
HAM-75-7.85
Retaining Wall U
PID No. 77889
Rii Project No. B-10-020**

Dear Mr. Kagel:

Resource International, Inc. (Rii) is pleased to submit this DRAFT structure foundation exploration report for the referenced project. Engineering logs have been prepared and are attached to this report along with the results of laboratory testing. This report includes recommendations for the design and construction of proposed Retaining Wall U as part of the HAM-75-7.85 project. The proposed wall will be located south of the proposed Seymour Avenue and I-75 interchange on the north side of Cincinnati, in Hamilton County, Ohio.

We sincerely appreciate the opportunity to be of service to you on this project. If you have any questions regarding the structure foundation exploration or this report, please contact us.

Sincerely,

RESOURCE INTERNATIONAL, INC.

A handwritten signature in blue ink that reads 'Brian R. Trenner'.

Brian R. Trenner, P.E.
Project Engineer

A handwritten signature in blue ink that reads 'Jonathan P. Sterenberg'.

Jonathan P. Sterenberg, P.E.
Director of Geotechnical Services

Enclosure: DRAFT Structure Foundation Exploration Report

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EXECUTIVE SUMMARY

Resource International, Inc. (Rii) has completed a DRAFT structure foundation exploration for the design and construction of proposed Retaining Wall U as part of the HAM-75-7.85 project, as shown on the vicinity map and boring plan presented in Appendix II of the full report. It is understood that a soldier pile and lagging wall type is being considered as the preferred wall type for the entire alignment of Retaining Wall U. The total wall length is approximately 450 lineal feet.

Exploration and Findings

On December 1 and 2, 2011, a total of three (3) structural borings, designated as B-025-0-11, B-027-0-11 and B-029-0-11, were drilled to depths of 50.0 feet each below the ground surface at the locations illustrated on the boring plan presented in Appendix II of the full report.

All of the borings were drilled at the top of the existing slope adjacent to the I-75 northbound lanes and encountered 5.0 to 7.0 inches of topsoil at the existing ground surface, identified by the significant presence of organic matter and vegetation.

Beneath the surface material in boring B-025, material identified as fill consisting of brown fine sand (ODOT A-3) was encountered to a depth of 3.0 feet below the ground surface. Underlying the surface materials and fill material in boring B-025, natural soils were encountered consisting of granular soils overlying cohesive soils. The granular soils were generally described as brown, brownish gray and gray gravel with sand and silt, gravel with sand, silt and clay, fine sand, coarse and fine sand and silt (ODOT A-2-4, A-2-6, A-3, A-3a, A-4b). The cohesive soils were generally described as gray, brownish gray and brown silt and clay, silty clay and clay (ODOT A-6a, A-6b, A-7-6) with lesser percentages of gravel and/or sand.

Bedrock was not encountered in any of the borings performed for this exploration.

Analyses and Recommendations

Design details of the proposed retaining wall were provided by the Rii design team. It is understood that the proposed retaining wall will be a soldier pile and lagging wall type that will be constructed adjacent to the east side of the widened portion of the I-75 northbound lanes. To accommodate the widened alignment, it is understood that a 2:1 (H:V) embankment will be graded behind the wall and extend up and back to tie in with the existing ground surface. To reduce the amount of excavation required to accommodate the new alignment, the retaining wall will be constructed in the area where grading the slope back from the proposed edge of the pavement is not desired due to the amount of cut that will be required.



Based upon proposed plan and cross section information provided by the Rii design team, wall heights along the alignment are anticipated to range between 5.3 feet and 15.8 feet. Based on the subsurface conditions encountered and the proposed geometry of the slope behind the wall, steel W-shape beams should be installed inside drilled shafts extending from the excavation bottom to the full wall height at each shaft location, and oriented with the web perpendicular to the wall alignment. Shafts and soldier piles employed for use in the retaining wall foundations may be proportioned based on the recommendations in the following table:

Drilled Shaft with Soldier Pile Foundation Recommendations

Wall Height (ft)	Proposed Elevations ¹ (ft msl)			Shaft Spacing (ft)	Shaft Diameter (in)	Embedment Depth ² (ft)	Pile Section
	Top	Ground	Tip				
H ≤ 8	571.5	563.5	574.5	8.0	30	8.0	W 18x86
8 < H ≤ 12	577.5	565.5	544.5	7.0	30	13.0	W 18x86
H > 12	580.5	564.7	540.7	6.0	30	16.0	W 18x86

1. Elevations estimated based on cross section information provided by the Rii design team. Actual elevations will vary along the alignment.
2. Embedment depth represents the length of the shaft required below the base of the wall.

Provided drilled shafts are proportioned as outlined above, a nominal end bearing resistance of $q_n = 11.0$ ksf at the strength limit state may be utilized for design. A geotechnical resistance factor of $\phi_n = 0.40$ should be considered when calculating the factored end bearing resistance. If additional resistance beyond the factored end bearing resistance is required, a nominal side resistance of $q_s = 1,500$ psf and geotechnical resistance factor of $\phi_s = 0.45$ should be considered for these shafts.

An analysis of the lateral deflection was performed for the wall heights listed in the previous table. For the center to center spacing, embedment depth and section type specified, the deflection determined from the LPILE analysis met the criteria of less than 1 percent of the wall height, and the section utilized met the structural capacity requirements.

Per Section 11.6.2.3 of the 2010 AASHTO LRFD BDS, overall (global) stability for walls not supporting structural foundations on spread footings is satisfied when a minimum factor of safety of 1.33 is obtained. Using the parameters provided in Section 5.1.2 of the full report in the section analyzed, a resulting factor of safety of 1.82 was determined for the maximum wall height at Station 469+50, satisfying the minimum requirement of 1.33.

Please note that this executive summary does not contain all the information presented in the report. The unabridged subsurface exploration report should be read in its entirety to obtain a more complete understanding of the information presented.



1.0 INTRODUCTION

The overall purpose of this project is to provide detailed subsurface information and recommendations for the design and construction of the HAM-75-7.85 project in Hamilton County, Ohio. This project represents the northern portion of HAM-75-2.30 Mill Creek Expressway improvements. The overall project will consist of roadway improvements, and several retaining wall and bridge replacements along I-75 from Vine Street to State Route 126. The project site is located in the community limits of St. Bernard, Elmwood Place, Roselawn, and Cincinnati, in Hamilton County, Ohio.

This DRAFT report is a presentation of the structure foundation exploration performed for the design and construction of proposed Retaining Wall U as part of the HAM-75-7.85 project, as shown on the vicinity map and boring plan presented in Appendix II. It is understood that a soldier pile and lagging wall type is being considered as the preferred wall type for the entire alignment of Retaining Wall U. The total wall length is approximately 450 lineal feet.

2.0 GEOLOGY AND OBSERVATIONS OF THE PROJECT

2.1 Site Geology

Both the Illinoian and Wisconsinan glaciers advanced over two-thirds of the State of Ohio, leaving behind glacial features such as moraines, kame deposits, lacustrine deposits and outwash terraces. The glacial and non-glacial regions comprise five physiographic sections grouped by age, depositional process and geomorphic occurrence. Physiographically, the site lies within the Illinoian Till Plain of the Till Plains Section. This area is characterized by rolling ground moraine deposits with many buried valleys alternating between broad floodplains and bedrock gorges. The site area contains silty loam till deposited as ground moraine covered with loess and dissected by the modern day Mill Creek. Ground moraines are deposited during the retreat of a glacier which results in an undifferentiated mixture of clay, silt, sand and gravel. The valley area also contains outwash and alluvium which eroded from hills and valleys with moderate relief. Outwash deposits consist of undifferentiated sand and gravel deposited by meltwater in front of glacial ice and often occurs as valley terraces or low plains. Alluvium and alluvial terrace deposits range in composition from silty clay size particles to cobbles, usually deposited in present and former floodplain areas.

Based on Bedrock Geology and Topography Maps of the area, from the Ohio Department of Natural Resources (ODNR), the underlying bedrock consists of the Ordovician-aged Point Pleasant Formation. The Point Pleasant Formation is comprised of interbedded limestone and shale, averaging 60 percent limestone and 40 percent shale, and ranges from 0 to 80 feet thick. The bedrock surface forms a valley roughly beneath, and following, the alignment of Mill Creek which is aligned northeast-to-southwest. I-75 is aligned roughly parallel to this main bedrock valley from the approximate intersection with State Route 126 to the approximate intersection with



Regina Graeter Way, and lies just east of the bottom of the bedrock valley. Along the project alignment, the bedrock surface directly beneath I-75 lies along the slope of the bedrock valley and the bedrock surface ranges between approximate elevations of 385 to 425 feet msl. A smaller bedrock valley branches off to the southeast of the bedrock valley that follows Mill Creek just south of the interchange with State Route 562, and runs roughly parallel with Ross Run and generally beneath the SR 562 alignment. Overall, the bedrock surface along the majority of the project alignment slopes downward to the northwest. According to bedrock topography mapping, the depth to top of bedrock in the vicinity of the project ranges from approximately 120 to 170 feet below the existing ground surface. An illustration of the general geology of Ohio is presented in Appendix I.

2.2 Existing Conditions

The site for the proposed Retaining Wall U is located along the east side of I-75, approximately 1,500 feet north of the Towne Street interchange with I-75 and just south of the ramp to the proposed Seymour Avenue and I-75 interchange. Overall, the project is located approximately 1.70 miles south of the Lockland split. The proposed wall begins at Station 466+27 and continues north to Station 470+65 along the east side of I-75. The wall will be located along the east side of I-75 and will be constructed in lieu of grading the existing slope to minimize the amount of excavation required to accommodate the proposed alignment. The existing I-75 roadway that runs adjacent to the proposed structure is currently a six-lane, asphalt paved road, and there is a vacant grass covered lot that lies east of the proposed retaining wall alignment. The terrain east of I-75 is elevated from the existing roadway and the I-75 mainline slopes downward gently from the north side of the proposed wall alignment to the south.

3.0 EXPLORATION

On December 1 and 2, 2011, a total of three (3) structural borings, designated as B-025-0-11, B-027-0-11 and B-029-0-11, were drilled to depths of 50.0 feet each below the ground surface at the locations illustrated on the boring plan presented in Appendix II.

Table 1. Test Boring Summary

Boring Number	Station	Offset	Latitude	Longitude	Ground Elevation (feet)	Boring Depth
B-025-0-11	466+82.88	103.8' Rt.	39.187437320 °N	84.481745821 °W	585.0	50.0
B-027-0-11	468+23.96	93.6' Rt.	39.187815061 °N	84.481630021 °W	581.2	50.0
B-029-0-11	469+18.29	117.6' Rt.	39.188042090 °N	84.481448909 °W	592.8	50.0



The boring locations were determined and located in the field by Rii representatives. Geographic latitude and longitude coordinates as well as ground surface elevations at the boring locations are included on the boring logs provided in Appendix IV.

The borings were drilled using an all terrain vehicle (ATV)-mounted rotary drilling machine, utilizing a 4.25-inch inside diameter, hollow-stem auger to advance the hole. Standard penetration testing (SPT) and split spoon sampling were performed in the boring at 2.5-foot increments of depth to 30 feet and at 5.0-foot increments thereafter to the boring termination depth. The SPT, per the American Society for Testing and Materials (ASTM) designation D1586, is conducted by letting a 140-pound hammer falling 30.0 inches to drive a 2.0-inch outer diameter split spoon sampler 18.0 inches. Rii utilized a calibrated automatic drop hammer to generate consistent energy transfer to the sampler. Driving resistance is recorded on the boring logs in terms of blows per 6-inch interval of the driving distance. The second and third intervals are added to obtain the number of blows per foot (N). Standard penetration blow counts aid in determining soil properties applicable in foundation system design. Measured blow count (N) values are corrected to an equivalent (60%) energy ratio, N_{60} , by the following equation. Both values are represented on boring logs in Appendix IV.

$$N_{60} = N_m * (ER/60)$$

Where:

N_m = measured N value

ER = drill rod energy ratio, expressed as a percent, for the system used

The hammer for the ATV-mounted drill rig used for this project was calibrated on May 6, 2011, and has a drill rod energy ratio of 77.1 percent.

During drilling, Rii personnel prepared field logs showing the encountered subsurface conditions. Soil samples obtained from the drilling operation were preserved and sealed in glass jars and delivered to the soil laboratory. In the laboratory, the soil samples were visually classified and select samples were tested, as noted in Table 2.

Table 2. Laboratory Test Schedule

Laboratory Test	Test Designation	Number of Tests Performed
Natural Moisture Content	ASTM D 2216	48
Plastic and Liquid Limits	AASHTO T89, T90	13
Sieve/Hydrometers	AASHTO T88	13
Unconfined Compression Test	ASTM D2166	1



The tests performed are necessary to classify existing soil according to the Ohio Department of Transportation (ODOT) classification system and to estimate engineering properties of importance in determining foundation design and construction recommendations. Results of the laboratory testing are presented, in part, on the boring logs in Appendix IV and also in Appendix V. A description of the soil terms used throughout this report is presented in Appendix III.

Hand penetrometer readings, which provide a rough estimate of the unconfined compressive strength of the soil, were reported on the boring logs in units of tons per square foot (tsf) and were utilized to classify the consistency of the cohesive soil in each layer. An indirect estimate of the unconfined compressive strength of the cohesive split spoon samples can also be made from a correlation with the blow counts (N_{60}). Please note that split spoon samples are considered to be disturbed and the laboratory determination of their shear strengths may vary from undisturbed conditions.

4.0 FINDINGS

Interpreted engineering logs have been prepared from the field logs, visual examination of samples, and laboratory testing. Classification follows the current version of the ODOT Specification for Geotechnical Exploration (SGE). The following is a summary of what was found in the test borings and what is represented on the boring logs.

4.1 Surficial Material

All of the borings were drilled at the top of the existing slope adjacent to the I-75 northbound lanes and encountered 5.0 to 7.0 inches of topsoil at the existing ground surface, identified by the significant presence of organic matter and vegetation.

4.2 Subsurface Soils

Beneath the surface material in boring B-025, material identified as fill consisting of brown fine sand (ODOT A-3) was encountered to a depth of 3.0 feet below the ground surface.

Underlying the surface materials and fill material in boring B-025, natural soils were encountered consisting of granular soils overlying cohesive soils. The granular soils were generally described as brown, brownish gray and gray gravel with sand and silt, gravel with sand, silt and clay, fine sand, coarse and fine sand and silt (ODOT A-2-4, A-2-6, A-3, A-3a, A-4b). The cohesive soils were generally described as gray, brownish gray and brown silt and clay, silty clay and clay (ODOT A-6a, A-6b, A-7-6) with lesser percentages of gravel and/or sand.

The relative density of granular soils is primarily derived from SPT blow counts (N_{60}). Based on the SPT blow counts obtained, the granular soil encountered ranged from



very loose ($N_{60} < 5$ blows per foot [bpf]) to very dense ($N_{60} > 50$ bpf). Overall blow counts recorded from the SPT sampling ranged from 3 to 58 bpf. The shear strength and consistency of the cohesive soils are primarily derived from the hand penetrometer values (HP). The cohesive soil encountered ranged from stiff ($1.0 < HP \leq 2.0$ tsf) to hard ($HP > 4.0$ tsf). The unconfined compressive strength of the cohesive soil samples tested, obtained from the hand penetrometer, ranged from 1.25 tsf to over 4.5 tsf (limit of the instrument).

Natural moisture contents of the soil samples tested ranged from 5 to 28 percent. The natural moisture contents of the cohesive soil samples tested for plasticity index ranged from 2 percent below to 9 percent above their corresponding plastic limits. The moisture contents of the native soils are generally considered to be slightly below to significantly above the optimum moisture levels.

4.3 Bedrock

Bedrock was not encountered in any of the borings performed for this exploration.

4.4 Groundwater

Groundwater was not encountered during the drilling process or at the completion of drilling in any of the borings performed. Please note that short-term water level readings, especially in cohesive soils, are not necessarily an accurate indication of the actual groundwater level. In addition, groundwater levels or the presence of groundwater are considered to be dependent on seasonal fluctuations in precipitation.

A more comprehensive description of what was encountered during the drilling process may be found on the boring logs in Appendix IV.

5.0 ANALYSES AND RECOMMENDATIONS

Data obtained from the drilling and testing program have been used to determine the foundation support capabilities and the settlement potential for the soil encountered at the site. These parameters have been used to provide guidelines for the design of foundation systems for the subject retaining wall, as well as the construction specifications related to the placement of foundation systems and general earthwork recommendations, which are discussed in the following paragraphs.

Design details of the proposed retaining wall were provided by the Rii design team. It is understood that the proposed retaining wall will be a soldier pile and lagging wall type that will be constructed adjacent to the east side of the widened portion of the I-75 northbound lanes. To accommodate the widened alignment, it is understood that a 2:1 (H:V) embankment will be graded behind the wall and extend up and back to tie in with the existing ground surface. To reduce the amount of excavation required to



accommodate the new alignment, the retaining wall will be constructed in the area where grading the slope back from the proposed edge of the pavement is not desired due to the amount of cut that will be required.

5.1 Retaining Wall Recommendations

Based upon proposed plan and cross section information provided by the Rii design team, wall heights along the alignment are anticipated to range between 5.3 feet and 15.8 feet. Based on the subsurface conditions encountered and the proposed geometry of the slope behind the wall, steel W-shape beams should be installed inside drilled shafts extending from the excavation bottom to the full wall height at each shaft location, and oriented with the web perpendicular to the wall alignment. Shafts and soldier piles employed for use in the retaining wall foundations may be proportioned based on the recommendations in Table 3:

Table 3. Drilled Shaft with Soldier Pile Foundation Recommendations

Wall Height (ft)	Proposed Elevations ¹ (ft msl)			Shaft Spacing (ft)	Shaft Diameter (in)	Embedment Depth ² (ft)	Pile Section
	Top	Ground	Tip				
H ≤ 8	571.5	563.5	555.5	8.0	30	8.0	W 18x86
8 < H ≤ 12	577.5	565.5	552.5	7.0	30	13.0	W 18x86
H > 12	580.5	564.7	548.7	6.0	30	16.0	W 18x86

1. Elevations estimated based on cross section information provided by the Rii design team. Actual elevations will vary along the alignment.
2. Embedment depth represents the length of the shaft required below the base of the wall.

The ground elevations listed in Table 3 coincide with the bottom of wall elevations, and the embedment depths reflect exclusively the length of the shaft in contact with the soil. The walls were evaluated to determine the center to center spacing required between the drilled shaft elements as well as the required embedment depth for the interval of wall heights listed in Table 3. Provided drilled shafts are proportioned as outlined above, a nominal end bearing resistance of $q_n = 11.0$ ksf at the strength limit state may be utilized for design. A geotechnical resistance factor of $\phi_n = 0.40$ should be considered when calculating the factored end bearing resistance. If additional resistance beyond the factored end bearing resistance is required, a nominal side resistance of $q_s = 1,500$ psf and geotechnical resistance factor of $\phi_s = 0.45$ should be considered for these shafts. Based on the above noted bearing resistance, a maximum settlement of the foundation is estimated to be 1.0-inch.



5.1.1 Lateral Design

The foundation elements for the soldier pile and lagging retaining walls were analyzed to verify that the pile section utilized has enough lateral and bending resistance to support the lateral load applied from the retained soil. It is understood that the maximum allowable lateral deflection is 1 percent of the wall height. Table 4 was used for lateral loading design:

Table 4. Lateral Design Parameters

Boring No.	Depth (feet)	Strata	Effective Unit Weight	Strength Parameter	k (soil)	ϵ_{50} (soil)
B-025-0-11	0-7.0	3	125 pcf	$C_u = 4,000$ psf	2000 pci	0.004
	7.0-21.0	3	120 pcf	$C_u = 2,750$ psf	1000 pci	0.006
	Below 21.0	3	125 pcf	$C_u = 4,000$ psf	2000 pci	0.004
B-027-0-11	0-7.0	3	120 pcf	$C_u = 2,500$ psf	1000 pci	0.006
	7.0-26.0	3	120 pcf	$C_u = 3,500$ psf	1000 pci	0.005
	Below 26.0	3	115 pcf	$C_u = 1,250$ psf	500 pci	0.007
B-029-0-11	0-3.5	3	125 pcf	$C_u = 4,000$ psf	2000 pci	0.004
	3.5-21.5	3	120 pcf	$C_u = 3,000$ psf	1000 pci	0.005
	Below 21.5	3	115 pcf	$C_u = 1,250$ psf	500 pci	0.007

1. Depth listed represents the depth below the ground surface at the base of the wall (embedment depth). Loading above the wall was modeled using a triangular load distribution.

In order to evaluate the lateral capacity, the LPILE Plus 5.0 program was utilized to determine the proper embedment depth and cross section to resist the lateral load for the given end condition and deflection criteria. Note that the table was prepared with a design groundwater elevation as indicated on the boring log. The following table lists the eleven different soil types internal to the LPILE Plus 5.0 program. These strata were utilized in Table 4 for evaluating the soil layers.

Table 5. Soil Strata Description

Strata	Description
1	Soft Clay
2	Stiff Clay with Water
3	Stiff Clay without Free Water
4	Sand (Reese)
5	User Defined
6	Vuggy Limestone (Strong Rock)
7	Silt (with cohesion and internal friction angle)
8	API Sand
9	Weak Rock
10	Liquefiable Sand (Rollins)
11	Stiff Clay without free water with a specified initial K (Brown)

Using the conditions and parameters in the previous tables, an analysis of the lateral deflection was performed for the wall heights listed in Table 3. For the center to center spacing, embedment depth and section type specified, the deflection determined from the LPILE analysis met the criteria of less than 1 percent of the wall height, and the section utilized met the structural capacity requirements.

5.1.2 Overall (Global) Stability

A slope stability analysis was performed to evaluate the global stability of the soldier pile and lagging retaining wall system. Global stability was checked at the maximum wall height of 15.8 feet, at Station 469+50. Soil parameters utilized in external stability analyses are presented in the following paragraphs. For the global stability condition, it was considered that the failure plane will not cross through the lagging, and that an increase in shear strength will occur due to soil arching between adjacent shafts where the soldier piles are embedded below the ground surface. The following long term strength parameters were utilized for the soil:



Table 6. Shear Strength Parameters Utilized in Stability Analyses

Material Type	Unit Weight, γ (pcf)	Long Term (Effective Stress) Parameters	
		ϕ' (°)	c' (psf)
Loose Fine Sand (ODOT A-3) ¹	120	27	0
Very Stiff Clay (ODOT A-7-6) ²	120	27	50
Very Dense Silt (ODOT A-4b) ¹	135	34	0
Very Stiff Silty Clay (ODOT A-6b) ³	120	32	0

1. Based on correlations with the energy corrected blow counts (N_{60}) within this zone.
2. Based on correlations with the plasticity index of the soil.
3. Based on laboratory consolidated undrained triaxial testing performed on an undisturbed sample from boring B-018-0-11.

The soldier piles were modeled in the slope stability analysis by incorporating a soil layer with a width and depth equal to the diameter and embedment depth of the shafts, respectively. The following shear strength parameters were assigned to this layer to model the shear strength increase due to soil arching between the shafts.

$$\begin{aligned} \S \phi &= 40^\circ \\ \S c &= 10,000 \text{ psf} \\ \S \gamma &= 140 \text{ pcf} \end{aligned}$$

Per Section 11.6.2.3 of the 2010 AASHTO LRFD BDS, overall (global) stability for walls not supporting structural foundations on spread footings is satisfied if the product of the factor of safety from the slope stability output multiplied by the resistance factor $\phi=0.75$ is greater than 1.0. Therefore, global stability is satisfied when a minimum factor of safety of 1.33 is obtained. Using the parameters above in the section analyzed, a resulting factor of safety of 1.82 was determined for the maximum wall height at Station 469+50, satisfying the minimum requirement of 1.33.

Calculations for wall deflection, structural capacity and overall (global) stability of the soldier pile and lagging retaining wall system are provided in Appendix VI.



5.2 Lateral Earth Pressure

For the soil types encountered in the borings, the “in-situ” unit weight (γ), cohesion (c), effective angle of friction (ϕ'), and lateral earth pressure coefficients for at-rest conditions (k_o), active conditions (k_a), and passive conditions (k_p) have been estimated and are provided in Table 7 and Table 8.

Table 7. Estimated Undrained (Short-term) Soil Parameters for Design

Soil Type	γ (pcf) ¹	c (psf)	ϕ	k_a ²	k_o	k_p ²
Stiff Cohesive Soil	115	1,250	0°	1.0	1.0	1.0
Very Stiff to Hard Cohesive Soil	120	3,000	0°	1.0	1.0	1.0
Very Loose to Loose Granular Soil	120	0	28°	0.36 / 0.65	0.53	2.77 / 1.23
Medium Dense Granular Soil	125	0	30°	0.33 / 0.54	0.50	3.00 / 1.49
Dense to Very Dense Granular Soil	135	0	34°	0.28 / 0.41	0.44	3.54 / 1.97
Compacted Cohesive Engineered Fill	125	1,500	0°	0.36 / 0.65	1.0	2.77 / 1.23
Compacted Granular Engineered Fill	135	0	33°	0.30 / 0.43	0.46	3.39 / 1.84

1. When below groundwater table, use effective unit weight, $g = g - 62.4$ pcf and add hydrostatic water pressure.
2. Where multiple values are listed, the first value is the earth pressure coefficient where the surface of the backfill is level, and the second value is the earth pressure coefficient where the surface of the backfill is sloped. Values listed for a sloped backfill are valid for slopes that are no steeper than 2:1 (H:V).

Table 8. Estimated Drained (Long-term) Soil Parameters for Design

Soil Type	γ (pcf) ¹	c (psf)	ϕ	k_a ²	k_o	k_p ²
Natural Cohesive Soil	120	0	26°	0.39 / 0.90	0.56	2.56 / 0.90
Very Loose to Loose Granular Soil	120	0	28°	0.36 / 0.65	0.53	2.77 / 1.23
Medium Dense Granular Soil	125	0	30°	0.33 / 0.54	0.50	3.00 / 1.49
Dense to Very Dense Granular Soil	135	0	34°	0.28 / 0.41	0.44	3.54 / 1.97
Compacted Cohesive Engineered Fill	125	0	28°	0.36 / 0.65	0.53	2.77 / 1.23
Compacted Granular Engineered Fill	135	0	33°	0.30 / 0.43	0.46	3.39 / 1.84

1. When below groundwater table, use effective unit weight, $g = g - 62.4$ pcf and add hydrostatic water pressure.
2. Where multiple values are listed, the first value is the earth pressure coefficient where the surface of the backfill is level, and the second value is the earth pressure coefficient where the surface of the backfill is sloped. Values listed for a sloped backfill are valid for slopes that are no steeper than 2:1 (H:V).

These parameters are considered appropriate for the design of subsurface walls and excavation support systems. It is recommended that the retaining wall structure be designed based on active conditions. The values in this table have been estimated from correlation charts based on minimum standards specified for compacted engineered fill materials. The first values listed in the columns for active and passive earth pressure do not take into account the effect of any surcharge loading or a sloped ground surface (a level surface is considered). The second values listed in these columns take into account a sloped ground surface along the surface of the backfill with a maximum slope angle of 2:1 (H:V). Earth pressures on excavation support systems will be dependent on the type of sheeting and method of bracing or anchorage.

5.3 Construction Considerations

All site work shall conform to local codes and to the latest ODOT Construction and Material Specifications (CMS), including that all excavation and embankment preparation and construction should follow ODOT Item 200 (Earthwork).

Fill soil placed for foundation support should be placed in loose lifts not to exceed 8.0 inches. Fill soil placed under structures shall be compacted to not less than 100 percent of the maximum dry density obtained by the Standard Proctor Test (ASTM D698). Fill soil containing excess moisture shall be required to dry prior to or during compaction to a moisture content not greater than 3.0 percent above or below optimum. However, for material that displays pronounced elasticity or deformation under the action of loaded rubber tire construction equipment, the moisture content shall be reduced to optimum if necessary to secure stability. Drying of wet soil shall be expedited by the use of plows, discs, or by other approved methods when so ordered by the site geotechnical engineer.

Generally, materials utilized for engineered fill should be free of waste construction debris and other deleterious materials and meet the following requirements:

- Maximum Dry Density per ASTM D698 > 110 pcf
- Liquid Limit < 40
- Plasticity Index < 15
- Organic Matter < 3 percent
- Maximum Particle Size < 3 inches
- Silt Content (between 0.075 and 0.005 mm) < 45 percent

Compacted granular fill shall meet the above specification and additionally shall have a maximum 35 percent passing the No. 200 sieve.



5.3.1 Excavation Considerations

All excavations should be shored / braced or laid back at a safe angle in accordance to Occupational Safety and Health Administration (OSHA) guidelines. During excavation, if slopes cannot be laid back to OSHA Standards due to adjacent structures or other obstructions, sheeting boxes may be required. The following table should be utilized as a general guide for implementing OSHA guidelines when estimating excavation back slopes at the various boring locations. Actual excavation back slopes must be field verified by qualified personnel at the time of excavation in strict accordance with OSHA guidelines.

Table 9. Excavation Back Slopes

Soil	Maximum Back Slope	Notes
Soft to Medium Stiff Cohesive	1.5 : 1.0	Above Ground Water Table and No Seepage
Stiff Cohesive	1.0 : 1.0	Above Ground Water Table and No Seepage
Very Stiff to Hard Cohesive	0.75 : 1.0	Above Ground Water Table and No Seepage
All Granular & Cohesive Soil Below Ground Water Table or with Seepage	1.5 : 1.0	None
Rock to 3.0' +/- below Auger Refusal	0.75 : 1.0	Above Ground Water Table and No Seepage
Stable Rock	Vertical	Above Ground Water Table and No Seepage

5.3.2 Groundwater Considerations

Based on the groundwater observations made during drilling, little to no groundwater seepage is anticipated during construction. However, where/if groundwater is encountered, proper groundwater control should be employed and maintained to prevent disturbance to excavation bottoms consisting of cohesive soil, and to prevent the possible development of a quick or "boiling" condition where soft silts and/or fine sands are encountered. It is preferable that the groundwater level, if encountered, be maintained at least 36 inches below the deepest excavation. Any seepage or groundwater encountered at this site should be able to be controlled by pumping from temporary sumps. Additional measures may be required depending on seasonal fluctuations of the groundwater level. Note that determining and maintaining actual groundwater levels during construction is the responsibility of the contractor.



6.0 LIMITATIONS OF STUDY

The above recommendations are predicated upon construction inspection by a qualified soil technician under the direct supervision of a professional geotechnical engineer. Adequate testing and inspection during construction are considered necessary to assure an adequate foundation system and are part of our recommendations.

Our recommendations for this project were developed utilizing soil and bedrock information obtained from the test borings that were made at the proposed site. At this time we would like to point out that soil borings only depict the soil and bedrock conditions at the specific locations and time at which they were made. The conditions at other locations on the site may differ from those occurring at the boring locations.

The conclusions and recommendations herein have been based upon the available soil and bedrock information and the design details furnished by a representative of the owner of the proposed project. Any revision in the plans for the proposed construction from those anticipated in this report should be brought to the attention of the geotechnical engineer to determine whether any changes in the foundation or earthwork recommendations are necessary. If deviations from the noted subsurface conditions are encountered during construction, they should also be brought to the attention of the geotechnical engineer.

The scope of our services does not include any environmental assessment or investigation for the presence or absence of hazardous or toxic materials in the soil, groundwater, or surface water within or beyond the site studied. Any statements in this report or on the test boring logs regarding odors, staining of soils, or other unusual conditions observed are strictly for the information of our client.

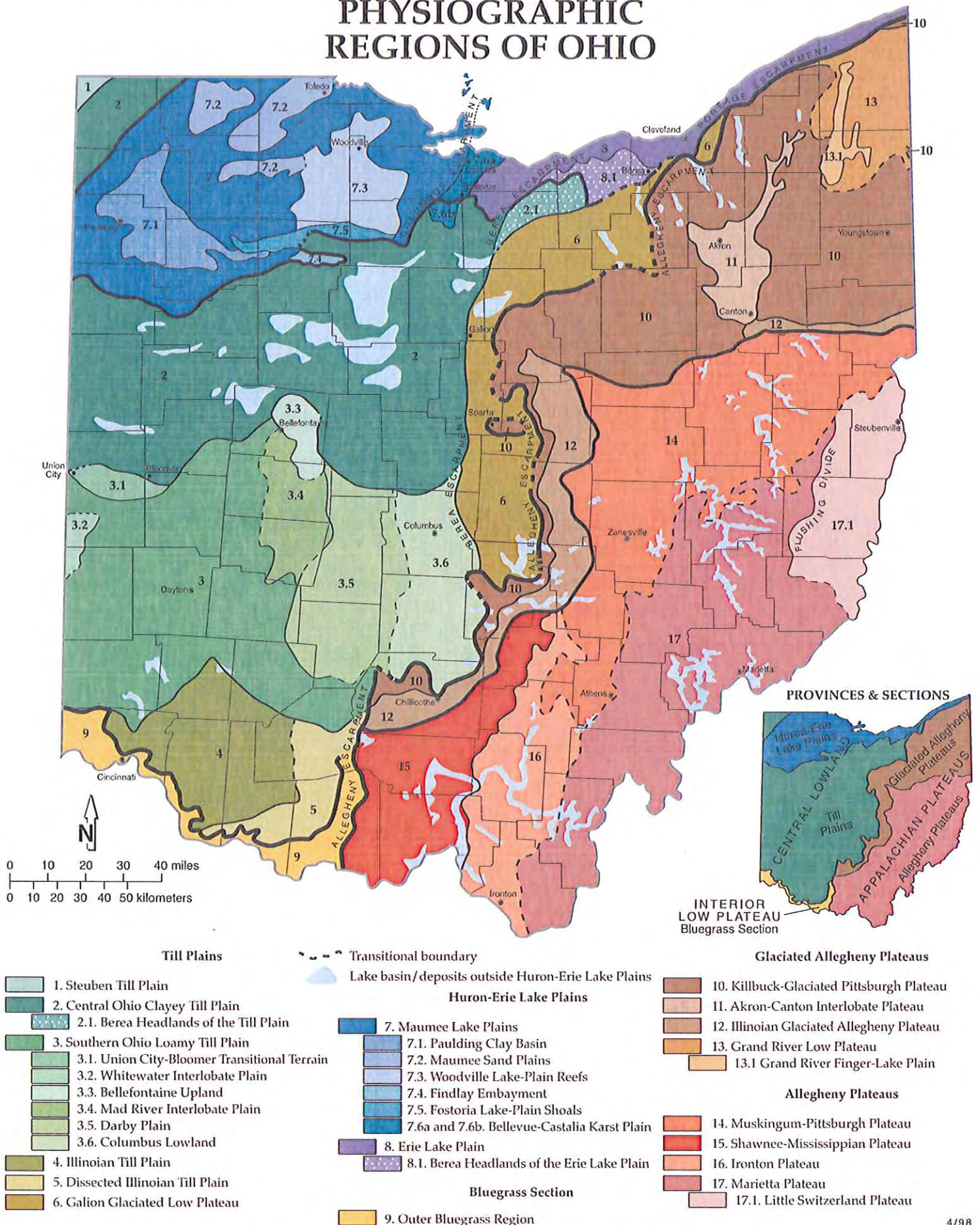
Our professional services have been performed, our findings obtained, and our recommendations prepared in accordance with generally accepted geotechnical engineering principles and practices. Resource International is not responsible for the conclusions, opinions, or recommendations made by others based upon the data included.



APPENDIX I

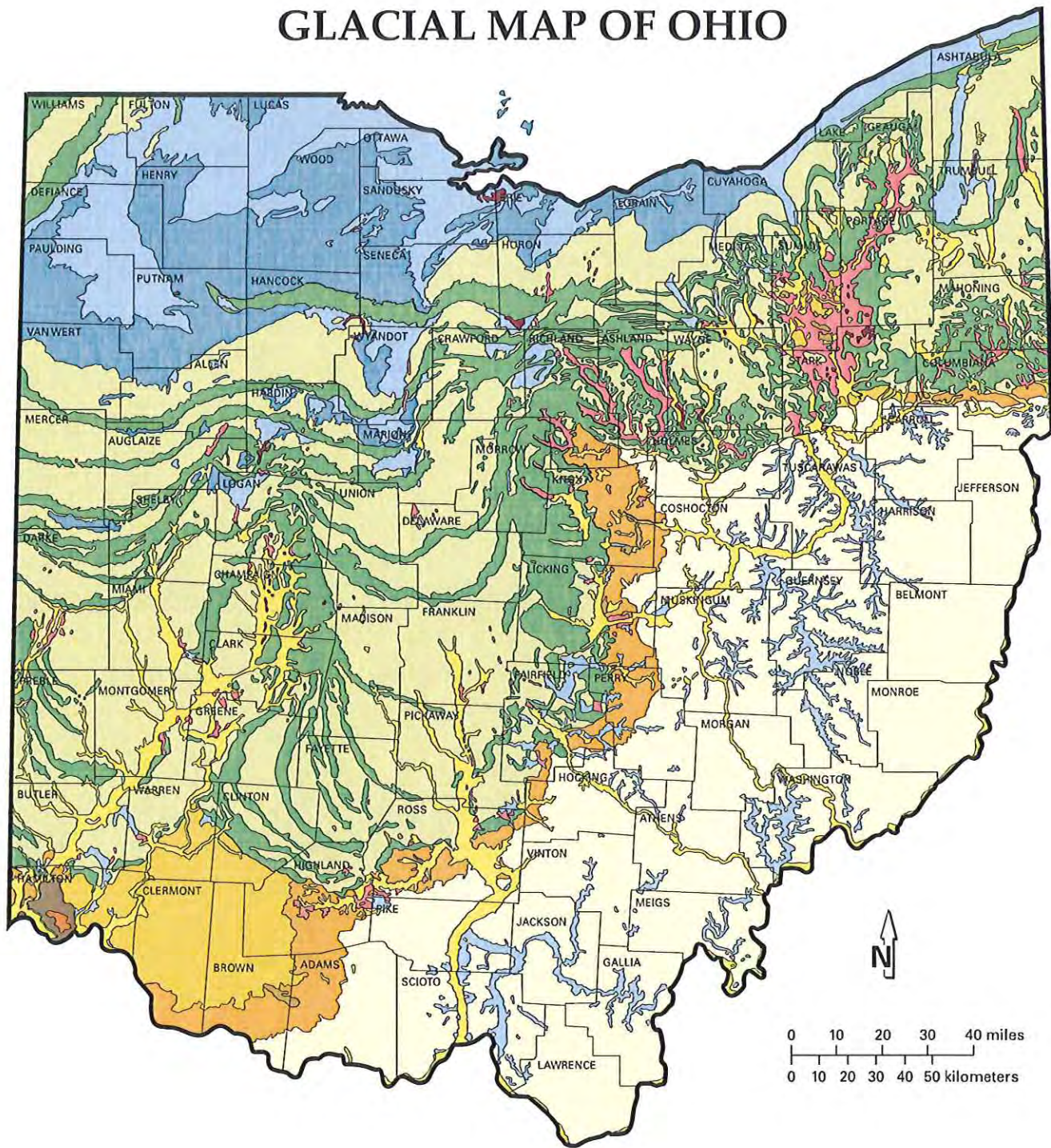
STATE GEOLOGY
















PHYSIOGRAPHIC REGIONS OF OHIO



- Till Plains**
- 1. Steuben Till Plain
 - 2. Central Ohio Clayey Till Plain
 - 2.1. Berea Headlands of the Till Plain
 - 3. Southern Ohio Loamy Till Plain
 - 3.1. Union City-Bloomer Transitional Terrain
 - 3.2. Whitewater Interlobate Plain
 - 3.3. Bellefontaine Upland
 - 3.4. Mad River Interlobate Plain
 - 3.5. Darby Plain
 - 3.6. Columbus Lowland
 - 4. Illinoian Till Plain
 - 5. Dissected Illinoian Till Plain
 - 6. Galion Glaciated Low Plateau
- Huron-Erie Lake Plains**
- 7. Maumee Lake Plains
 - 7.1. Paulding Clay Basin
 - 7.2. Maumee Sand Plains
 - 7.3. Woodville Lake-Plain Reefs
 - 7.4. Findlay Embayment
 - 7.5. Fostoria Lake-Plain Shoals
 - 7.6a and 7.6b. Bellevue-Castalia Karst Plain
 - 8. Erie Lake Plain
 - 8.1. Berea Headlands of the Erie Lake Plain
- Bluegrass Section**
- 9. Outer Bluegrass Region
- Glaciated Allegheny Plateaus**
- 10. Killbuck-Glaciated Pittsburgh Plateau
 - 11. Akron-Canton Interlobate Plateau
 - 12. Illinoian Glaciated Allegheny Plateau
 - 13. Grand River Low Plateau
 - 13.1 Grand River Finger-Lake Plain
- Allegheny Plateaus**
- 14. Muskingum-Pittsburgh Plateau
 - 15. Shawnee-Mississippian Plateau
 - 16. Ironton Plateau
 - 17. Marietta Plateau
 - 17.1. Little Switzerland Plateau
- PROVINCES & SECTIONS**
- Interior Low Plateau Bluegrass Section
 - Central Lowland
 - Huron-Erie Lake Plains
 - Till Plains
 - Glaciated Allegheny Plateaus
 - Appalachian Plateaus
 - Allegheny Plateaus

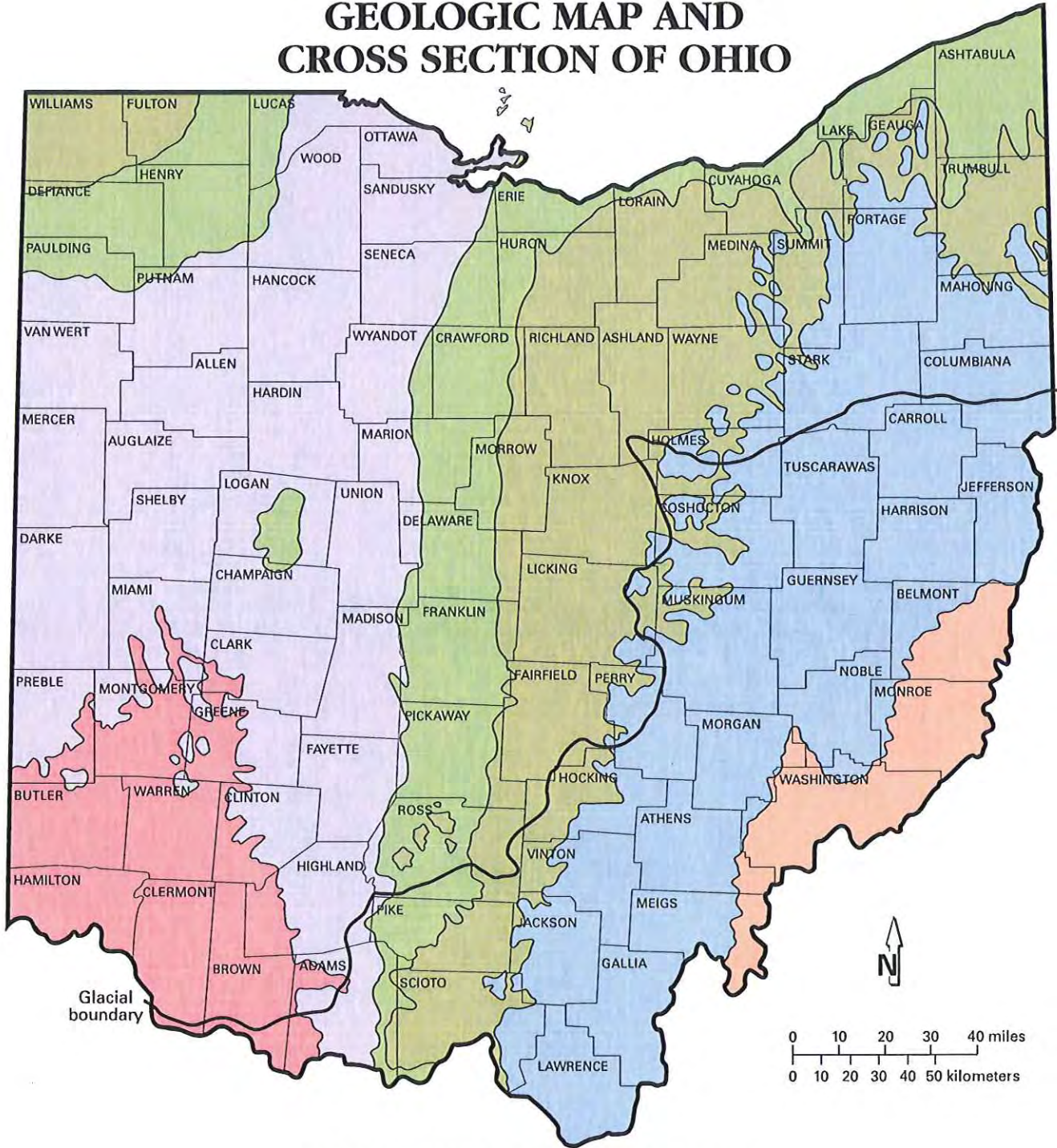
GLACIAL MAP OF OHIO









WISCONSINAN (14,000 to 24,000 years old)		ILLINOIAN (130,000 to 300,000 years old)		PRE-ILLINOIAN (older than 300,000 years)		 Kames and eskers
 Ground moraine	 Ground moraine	 Ground moraine	 Ground moraine	 Outwash	 Lake deposits	 Peat
 Wave-planed ground moraine	 Dissected ground moraine	 Dissected ground moraine	 Dissected ground moraine	 Colluvium		
 End moraine	 Hummocky moraine					

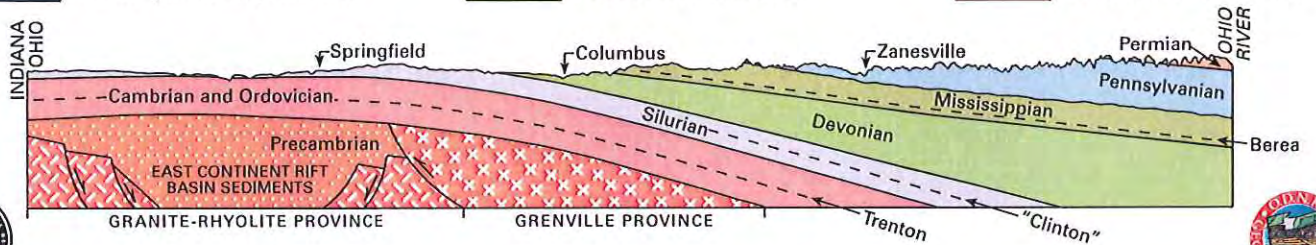


GEOLOGIC MAP AND CROSS SECTION OF OHIO



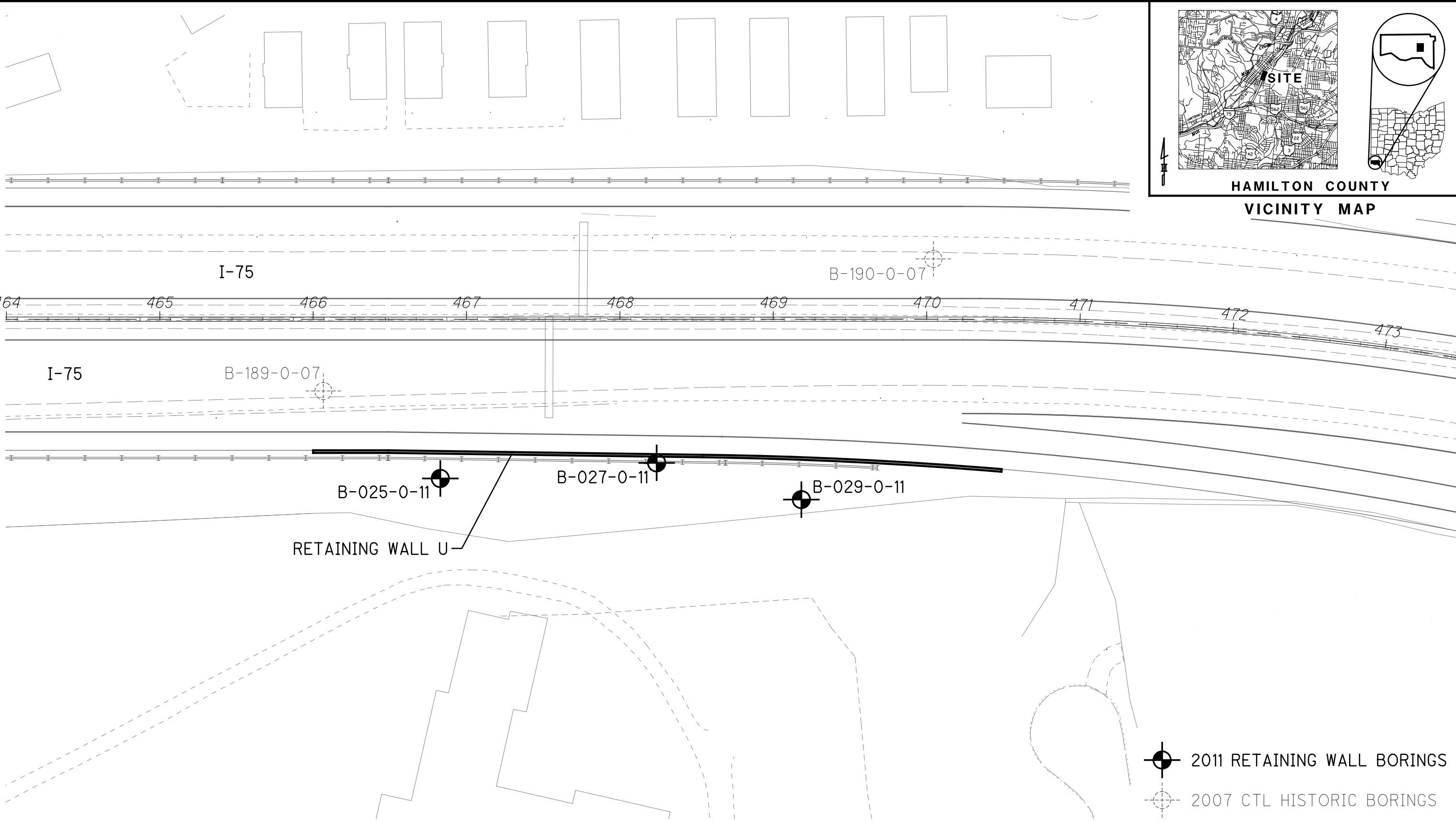
GEOLOGIC SYSTEM (million years before present)

- | | | |
|---|---|--|
|  Permian (286-245) |  Mississippian (360-320) |  Silurian (438-408) |
|  Pennsylvanian (320-286) |  Devonian (408-360) |  Ordovician (505-438) |



APPENDIX II

VICINITY MAP AND BORING PLAN

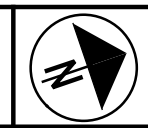


BORING PLAN
HAM-75-7.85 RETAINING WALL U
HAMILTON COUNTY, OHIO

PROJECT NO.
Rii B-10-020

SCALE: 1"=60'

0 30 60



DRAWN
RRM

REVIEWED
BRT

DATE
5-9-12



APPENDIX III

DESCRIPTION OF SOIL TERMS

DESCRIPTION OF SOIL TERMS

The following terminology was used to describe soils throughout this report and is generally adapted from ASTM 2487/2488 and ODOT Specifications for Geotechnical Explorations.

Granular Soils - The relative compactness of granular soils is described as:
ODOT A-1, A-2, A-3, A-4 (non-plastic) or USCS GW, GP, GM, GC, SW, SP, SM, SC, ML (non-plastic)

<u>Description</u>	<u>Blows per foot – SPT (N₆₀)</u>	
Very Loose	Below	5
Loose	5	- 10
Medium Dense	11	- 30
Dense	31	- 50
Very Dense	Over	50

Cohesive Soils - The relative consistency of cohesive soils is described as:
ODOT A-4, A-5, A-6, A-7, A-8 or USCS ML, CL, OL, MH, CH, OH, PT

<u>Description</u>	<u>Blows per foot – SPT (N₆₀)</u>		<u>Unconfined Compression (tsf)</u>
Very Soft	Below	2	UCS ≤ 0.25
Soft	2	- 4	0.25 < UCS ≤ 0.5
Medium Stiff	5	- 8	0.5 < UCS ≤ 1.0
Stiff	9	- 15	1.0 < UCS ≤ 2.0
Very Stiff	16	- 30	2.0 < UCS ≤ 4.0
Hard	Over	30	UCS > 4.0

Gradation - The following size-related denominations are used to describe soils:

<u>Soil Fraction</u>	<u>USCS Size</u>	<u>ODOT Size</u>
Boulders	Larger than 12"	Larger than 12"
Cobbles	12" to 3"	12" to 3"
Gravel coarse	3" to ¾"	3" to ¾"
Gravel fine	¾" to 4.75 mm (¾" to #4 Sieve)	¾" to 2.0 mm (¾" to #10 Sieve)
Sand coarse	4.75 mm to 2.0 mm (#4 to #10 Sieve)	2.0 mm to 0.42 mm (#10 to #40 Sieve)
Sand medium	2.0 mm to 0.42 mm (#10 to #40 Sieve)	-
Sand fine	0.42 mm to 0.074 mm (#40 to #200 Sieve)	0.42 mm to 0.074 mm (#40 to #200 Sieve)
Silt	0.074 mm to 0.005 mm (#200 to 0.005 mm)	0.074 mm to 0.005 mm (#200 to 0.005 mm)
Clay	Smaller than 0.005 mm	Smaller than 0.005 mm

Modifiers of Components - Modifiers of components are as follows:

<u>Term</u>	<u>Range</u>	
Trace	0%	- 10%
Little	10%	- 20%
Some	20%	- 35%
And	35%	- 50%

Moisture Table - The following moisture-related denominations are used to describe cohesive soils:

<u>Term</u>	<u>Range - USCS</u>	<u>Range - ODOT</u>
Dry	0% to 10%	Well below Plastic Limit
Damp	>2% below Plastic Limit	Below Plastic Limit
Moist	2% below to 2% above Plastic Limit	Above PL to 3% below LL
Very Moist	>2% above Plastic Limit	
Wet	≥ Liquid Limit	3% below LL to above LL

Organic Content – The following terms are used to describe organic soils:

<u>Term</u>	<u>Organic Content (%)</u>
Slightly organic	2-4
Moderately organic	4-10
Highly organic	>10

Bedrock – The following terms are used to describe bedrock hardness:

<u>Term</u>	<u>Blows per foot – SPT (N)</u>	
Very Soft	Below	50
Soft	50/5"	- 50/6"
Medium Hard	50/3"	- 50/4"
Hard	50/1"	- 50/2"
Very Hard	50/0"	



CLASSIFICATION OF SOILS

Ohio Department of Transportation

(The classification of a soil is found by proceeding from top to bottom of the chart.
The first classification that the test data fits is the correct classification.)

SYMBOL	DESCRIPTION	Classification		LL _O /LL _L x 100*	% Pass #40	% Pass #200	Liquid Limit (LL)	Plastic Index (PI)	Group Index Max.	REMARKS
		AASHTO	OHIO							
	Gravel and/or Stone Fragments	A-1-a			30 Max.	15 Max.		6 Max.	0	Min. of 50% combined gravel, cobble and boulder sizes
	Gravel and/or Stone Fragments with Sand	A-1-b			50 Max.	25 Max.		6 Max.	0	
	Fine Sand	A-3			51 Min.	10 Max.	NON-PLASTIC		0	
	Coarse and Fine Sand	--	A-3a			35 Max.		6 Max.	0	Min. of 50% combined coarse and fine sand sizes
	Gravel and/or Stone Fragments with Sand and Silt	A-2-4			35 Max.		40 Max.	10 Max.	0	
		A-2-5		41 Min.						
	Gravel and/or Stone Fragments with Sand, Silt and Clay	A-2-6			35 Max.		40 Max.	11 Min.	4	
		A-2-7		41 Min.						
	Sandy Silt	A-4	A-4a	76 Min.		36 Min.	40 Max.	10 Max.	8	Less than 50% silt sizes
	Silt	A-4	A-4b	76 Min.		50 Min.	40 Max.	10 Max.	8	50% or more silt sizes
	Elastic Silt and Clay	A-5		76 Min.		36 Min.	41 Min.	10 Max.	12	
	Silt and Clay	A-6	A-6a	76 Min.		36 Min.	40 Max.	11 - 15	10	
	Silty Clay	A-6	A-6b	76 Min.		36 Min.	40 Max.	16 Min.	16	
	Elastic Clay	A-7-5		76 Min.		36 Min.	41 Min.	≤ LL-30	20	
	Clay	A-7-6		76 Min.		36 Min.	41 Min.	> LL-30	20	
	Organic Silt	A-8	A-8a	75 Max.		36 Min.				W/o organics would classify as A-4a or A-4b
	Organic Clay	A-8	A-8b	75 Max.		36 Min.				W/o organics would classify as A-5, A-6a, A-6b, A-7-5 or A-7-6

MATERIAL CLASSIFIED BY VISUAL INSPECTION



Sod and Topsoil



Pavement or Base



Uncontrolled Fill (Describe)



Bouldery Zone



Peat, S-Sedimentary
W-Woody F-Fibrous
L-Loamy & etc

* Only perform the oven-dried liquid limit test and this calculation if organic material is present in the sample.

APPENDIX IV

BORING LOGS:

B-025-0-11, B-027-0-11 AND B-029-0-11

Definitions of Abbreviations for Boring Logs

A	=	Adhesion (pounds per square foot)
AS	=	Auger Sample
BCP	=	Bentonite Chips or Pellets
C	=	Cohesion (pounds per square foot)
CB	=	Cased (Concentric) Boring
C/B	=	Neat Cement/Bentonite Grout
Cl ⁻	=	Chloride Ion Concentration (parts per million)
FA	=	Angle of Internal Friction (degrees)
FF	=	Friction Factor
GS	=	Geoprobe Sample
HSA	=	Hollow Stem Auger
HSB	=	High Solids Content Bentonite Grout
K	=	Modulus of Horizontal Subgrade Reaction (kips per cubic foot)
LOI	=	Percent Organic Content (by weight) as determined by ASTM D-2974 (loss on ignition test)
MD	=	Rotary Mud Drilling
NQ	=	Wireline Method (1.875-inch diameter rock core)
NX	=	Conventional Method (2.126-inch diameter rock core)
PC	=	Neat Portland Cement Grout
PID	=	Photo-Ionization Detector Reading (parts per million)
qh	=	Unconfined Compressive Strength of Soil as determined by a hand penetrometer (tons per square foot)
qr	=	Unconfined Compressive Strength of Intact Rock Core as determined by ASTM D-2938 (pounds per square inch)
qu	=	Unconfined Compressive Strength of Soil as determined by ASTM D-2166 (tons per square foot)
quu	=	Unconsolidated-Undrained Triaxial Compressive Strength as determined by ASTM D-2850 (pounds per square foot)
RC	=	Rock Coring
SO ⁴⁻	=	Sulfate Concentration
SFA	=	Solid Flight Auger
SS	=	Split Spoon Sample
3S	=	For instances of no recovery from standard SS interval, a 3.0 inch O.D. split spoon is driven the full length of the standard SS interval plus an additional 6.0 inches to obtain a representative sample. Only the final 6.0 inches of sample is retained. Blow counts from 3S sampling are not correlated with N ₆₀ values.
ss	=	Soluble Salts (conductivity)
ST	=	Thin-walled (Shelby) Tube Sample
uw	=	"In-Situ" Unit Weight of Soil (pounds per cubic foot)
VIS	=	Visual classification only, no testing performed
WOH	=	Weight of Hammer and Drill Rods "pushed" split spoon sampler 6-inches.
WD	=	Rotary Wash Drilling

2010 ODOT BORING LOG-RII-WITH LAT/LONG - 5/22/12 07:24 - C:\GINT8\PROJECTS\2010\B-10-020\B-10-020 B-27 B-29 RET WALLS.GPJ

PID: 77889 BR ID: NA PROJECT: HAM-75-7.85 STATION / OFFSET: 466+82.88 / 103.8' Rt START: 12/1/11 END: 12/1/11 PG 2 OF 2 B-025-0-11

MATERIAL DESCRIPTION AND NOTES	ELEV.	DEPTHS	SPT/ RQD	N ₆₀	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%)					ATTERBERG			WC	ODOT CLASS (GI)	BACK FILL	
								GR	CS	FS	SI	CL	LL	PL	PI				
VERY STIFF, GRAY CLAY , SOME SILT, TRACE FINE SAND, MOIST.	557.0	29															A-7-6 (17)		
		30			71	ST-12	2.75	0	0	1	30	69	51	23	28	23			
VERY STIFF, BROWNISH GRAY SILTY CLAY , TRACE COARSE TO FINE SAND, MOIST.	553.0	31															A-6b (V)		
		34	5	7	13	26	100	SS-13	3.50	-	-	-	-	-	-	-		27	
HARD, GRAY SILT AND CLAY , LITTLE COARSE TO FINE SAND, TRACE FINE GRAVEL, DAMP.	543.0	39	5	7	9	21	100	SS-14	2.50	0	1	2	42	55	36	18	18	27	A-6b (11)
		44	5	10	15	32	100	SS-15	4.25	-	-	-	-	-	-	-	-	11	A-6a (V)
	535.0	49	6	10	14	31	100	SS-16	4.50	-	-	-	-	-	-	-	-	10	A-6a (V)
		50																	

EOB

NOTES: GROUNDWATER NOT ENCOUNTERED DURING DRILLING; CAVE-IN DEPTH @ 30.0'
 ABANDONMENT METHODS, MATERIALS, QUANTITIES: COMPACTED WITH THE AUGER 50 LBS BENTONITE CHIPS AND SOIL CUTTINGS


2010 ODOT BORING LOG-R11-WITH LAT/LONG - 5/22/12 07:24 - C:\GINT8\PROJECTS\2010\B-10-020\B-10-020 B-25 B-27 B-29 RET WALLS.GPJ

PID: 77889 BR ID: NA PROJECT: HAM-75-7.85 STATION / OFFSET: 468+23.96 / 93.6' Rt START: 12/1/11 END: 12/1/11 PG 2 OF 2 B-027-0-11




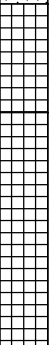


MATERIAL DESCRIPTION AND NOTES	ELEV.	DEPTHS	SPT/ RQD	N ₆₀	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%)					ATTERBERG			WC	ODOT CLASS (GI)	BACK FILL		
								GR	CS	FS	SI	CL	LL	PL	PI					
VERY STIFF TO HARD, BROWN CHANGING TO BROWNISH GRAY CLAY , SOME SILT, TRACE COARSE TO FINE SAND, DAMP TO MOIST. (same as above)	553.2	29	8	30	100	SS-12	4.5+	-	-	-	-	-	-	-	-	-	21	A-7-6 (V)	< \ / >	
		30	15																< \ / >	
		31																		< \ / >
		32																		< \ / >
		33																		< \ / >
		34	9	8	22	100	SS-13	4.00	-	-	-	-	-	-	-	-	-	24	A-7-6 (V)	< \ / >
		35		9																< \ / >
		36																		< \ / >
		37																		< \ / >
		38																		< \ / >
STIFF, GRAY CLAY , SOME SILT, TRACE FINE SAND, MOIST.	539.2	39	4	6	17	89	SS-14	4.00	-	-	-	-	-	-	-	-	23	A-7-6 (V)	< \ / >	
		40	7																	< \ / >
		41																		< \ / >
		42																		< \ / >
		43																		< \ / >
		44	3	4	13	100	SS-15	1.25	0	0	1	30	69	46	20	26	28	A-7-6 (16)	< \ / >	
		45		6																< \ / >
		46																		< \ / >
		47																		< \ / >
		48																		< \ / >
	531.2	49	4	4	14	89	SS-16	1.25	-	-	-	-	-	-	-	-	26	A-7-6 (V)	< \ / >	
		50	7																< \ / >	

EOB

NOTES: GROUNDWATER NOT ENCOUNTERED DURING DRILLING
 ABANDONMENT METHODS, MATERIALS, QUANTITIES: COMPACTED WITH THE AUGER 50 LBS BENTONITE CHIPS AND SOIL CUTTINGS

	PROJECT: HAM-75-7.85	DRILLING FIRM / OPERATOR: RII / T.F.	DRILL RIG: CME-750X (SN 310218)	STATION / OFFSET: 469+18.29 / 117.6' Rt	EXPLORATION ID B-029-0-11
	TYPE: RETAINING WALL	SAMPLING FIRM / LOGGER: RII / S.M.	HAMMER: CME AUTOMATIC	ALIGNMENT: PROPOSED CL I-75	
	PID: 77889 BR ID: NA	DRILLING METHOD: 4.25" HSA	CALIBRATION DATE: 5/6/11	ELEVATION: 592.8 (MSL) EOB: 50.0 ft.	PAGE
	START: 12/2/11 END: 12/2/11	SAMPLING METHOD: SPT	ENERGY RATIO (%): 77.1	LAT / LONG : 39.18804209 ° N / 84.481448909 ° W	1 OF 2

2010 ODOT BORING LOG-RII-WITH LAT/LONG - 5/22/12 07:24 - C:\GINT8\PROJECTS\2010\B-10-020\B-10-020\B-27 B-29 RET WALLS.GPJ

MATERIAL DESCRIPTION AND NOTES	ELEV.	DEPTHS	SPT/RQD	N ₆₀	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%)					ATTERBERG			WC	ODOT CLASS (GI)	BACK FILL
								GR	CS	FS	SI	CL	LL	PL	PI			
0.4' - TOPSOIL (5.0") VERY LOOSE TO LOOSE, BROWN FINE SAND, SOME COARSE SAND, TRACE SILT, TRACE CLAY, DAMP.	592.8																	
 FS	592.4	1	1	3	100	SS-1	-	-	-	-	-	-	-	-	6	A-3 (V)		
		2	1	3	100	SS-2	-	0	34	58	6	2	NP	NP	NP	7		A-3 (0)
		3																
		4	2	1	3	100	SS-3	-	-	-	-	-	-	-	-	6		A-3 (V)
	584.8	5																
STIFF, BROWNISH GRAY CLAY, AND SILT, LITTLE COARSE TO FINE SAND, MOIST.	582.3	6	2	5	100	SS-4	1.25	-	-	-	-	-	-	-	23	A-7-6 (V)		
		7	3	9	78	SS-5	3.00	-	-	-	-	-	-	-	20	A-7-6 (V)		
		8	3	4	19	78	SS-5	3.00	-	-	-	-	-	-	-	20		A-7-6 (V)
VERY STIFF TO HARD, BROWN TO BROWNISH GRAY CLAY, AND SILT, LITTLE COARSE TO FINE SAND, DAMP TO MOIST.	576.8	9	6	9	78	SS-5	3.00	-	-	-	-	-	-	-	20	A-7-6 (V)		
 -qu @ 14.8' = 2.96 tsf		10			75	ST-6	2.75	0	3	9	37	51	53	22	31	22		A-7-6 (19)
		11																
HARD, BROWNISH GRAY SILT AND CLAY, TRACE COARSE TO FINE SAND, MOIST.	572.3	12	5	11	32	89	SS-7	4.5+	-	-	-	-	-	-	17	A-6a (V)		
		13	9	13	46	100	SS-8	4.5+	-	-	-	-	-	-	18	A-6a (V)		
		14	11	14	46	94	SS-9	-	-	-	-	-	-	-	18	A-4b (V)		
		15	7	14	46	94	SS-9	-	-	-	-	-	-	-	18	A-4b (V)		
		16	9	13	53	78	SS-10	-	0	0	10	71	19	NP	NP	NP	21	A-4b (8)
DENSE TO VERY DENSE, BROWNISH GRAY CHANGING TO GRAY SILT, LITTLE CLAY, TRACE FINE SAND, MOIST TO WET.	564.8	17	11	14	58	100	SS-11	-	-	-	-	-	-	-	24	A-4b (V)		

2010 ODOT BORING LOG-R11-WITH LAT/LONG - 5/22/12 07:24 - C:\GINT8\PROJECTS\2010\B-10-020\B-10-020 B-25 B-27 B-29 RET WALLS.GPJ

PID: 77889 BR ID: NA PROJECT: HAM-75-7.85 STATION / OFFSET: 469+18.29 / 117.6' Rt START: 12/2/11 END: 12/2/11 PG 2 OF 2 B-029-0-11

MATERIAL DESCRIPTION AND NOTES	ELEV.	DEPTHS	SPT/ RQD	N ₆₀	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%)					ATTERBERG			WC	ODOT CLASS (GI)	BACK FILL	
								GR	CS	FS	SI	CL	LL	PL	PI				
HARD, GRAY SILT AND CLAY , LITTLE FINE SAND, TRACE FINE GRAVEL, MOIST.	564.8	29	15	45	100	SS-12	4.5+	-	-	-	-	-	-	-	-	20	A-6a (V)	↖ ↗ ↘ ↙	
		30	20																15
VERY STIFF, GRAY SILTY CLAY , MOIST.	560.8	31																↖ ↗ ↘ ↙	
		32																	↖ ↗ ↘ ↙
		33																	↖ ↗ ↘ ↙
		34	4	7	22	100	SS-13	3.00	-	-	-	-	-	-	-	-	22	A-6b (V)	↖ ↗ ↘ ↙
		35		10															↖ ↗ ↘ ↙
		36																	↖ ↗ ↘ ↙
		37																	↖ ↗ ↘ ↙
		38																	↖ ↗ ↘ ↙
		39	6	8	22	100	SS-14	3.50	0	0	0	47	53	40	19	21	24	A-6b (12)	↖ ↗ ↘ ↙
		40		9															↖ ↗ ↘ ↙
41																		↖ ↗ ↘ ↙	
42																		↖ ↗ ↘ ↙	
43																		↖ ↗ ↘ ↙	
44	4	5	14	100	SS-15	3.25	-	-	-	-	-	-	-	-	20	A-6b (V)	↖ ↗ ↘ ↙		
45		6																↖ ↗ ↘ ↙	
46																		↖ ↗ ↘ ↙	
47																		↖ ↗ ↘ ↙	
48																		↖ ↗ ↘ ↙	
49	3	6	14	100	SS-16	2.50	-	-	-	-	-	-	-	-	27	A-6b (V)	↖ ↗ ↘ ↙		
	542.8	50	5															↖ ↗ ↘ ↙	

EOB

NOTES: GROUNDWATER NOT ENCOUNTERED DURING DRILLING; CAVE-IN DEPTH @ 15.7'
 ABANDONMENT METHODS, MATERIALS, QUANTITIES: COMPACTED WITH THE AUGER 50 LBS BENTONITE CHIPS AND SOIL CUTTINGS

APPENDIX V

LABORATORY TEST RESULTS



6350 Presidential Gateway
 Columbus, Ohio 43231
 Telephone: (614) 823-4949
 Fax Number: (614) 823-4990

UNCONFINED COMPRESSION

ASTM D -2166

PROJECT HAM-75-7.85
 JOB No. B-10-020

BORING / SAMPLE No. B-029-0-11 / ST-6
 SAMPLE DEPTH 14.8 feet
 DATE OF TESTING December 7, 2011
 TESTED BY J.H.

SOIL DESCRIPTION: Brown and brownish gray CLAY, and silt, little coarse to fine sand

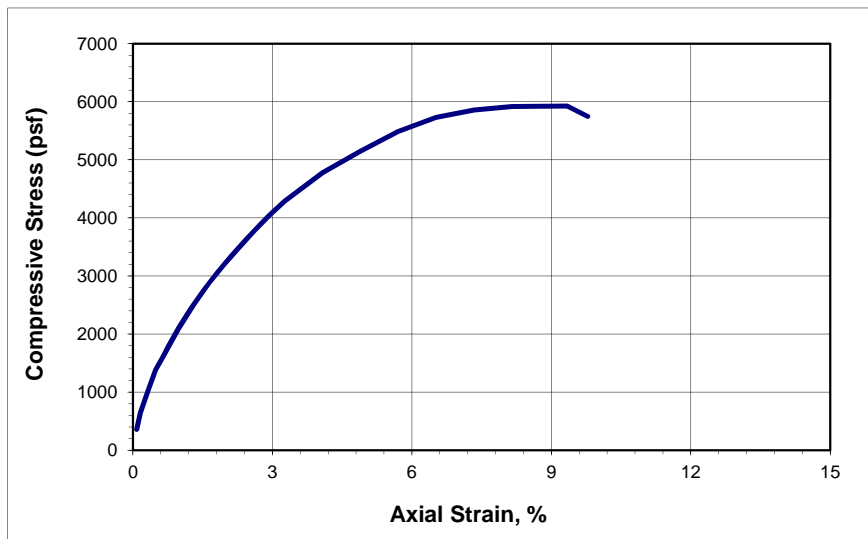
Physical Characteristics	L.L.	P.L.	P.I.	Gravel%	C. Sand%	F. Sand%	Silt%	Clay%
	53	22	31	0	3	9	37	51

DIAMETER, D ₀	<u>2.767 in</u>	<u>70.282 mm</u>	STRAIN RATE	<u>1.0</u>	%/min	
AREA, A ₀	<u>6.0132 in²</u>	<u>38.795 cm²</u>	WET SOIL + PAN MASS	<u>1391.1</u>	g	
HEIGHT, L ₀	<u>6.133 in</u>	<u>155.78 mm</u>	PAN MASS	<u>56.2</u>	g	
VOLUME, V ₀	<u>36.879 in³</u>	<u>604.34 cm³</u>	DRY SOIL + PAN MASS	<u>1175.4</u>	g	
MACH. RATE	<u>0.613</u>	in/min	WET DENSITY	<u>137.89</u>	lb/ft ³	
WATER CONT.	<u>19.27</u>	%	DRY DENSITY	<u>115.61</u>	lb/ft ³	
UNCONFINED COMPRESSION STRESS, q _u			5927	psf	<u>2.96</u>	tsf
HAND PENETROMETER					<u>2.75</u>	tsf

Failure Sketch

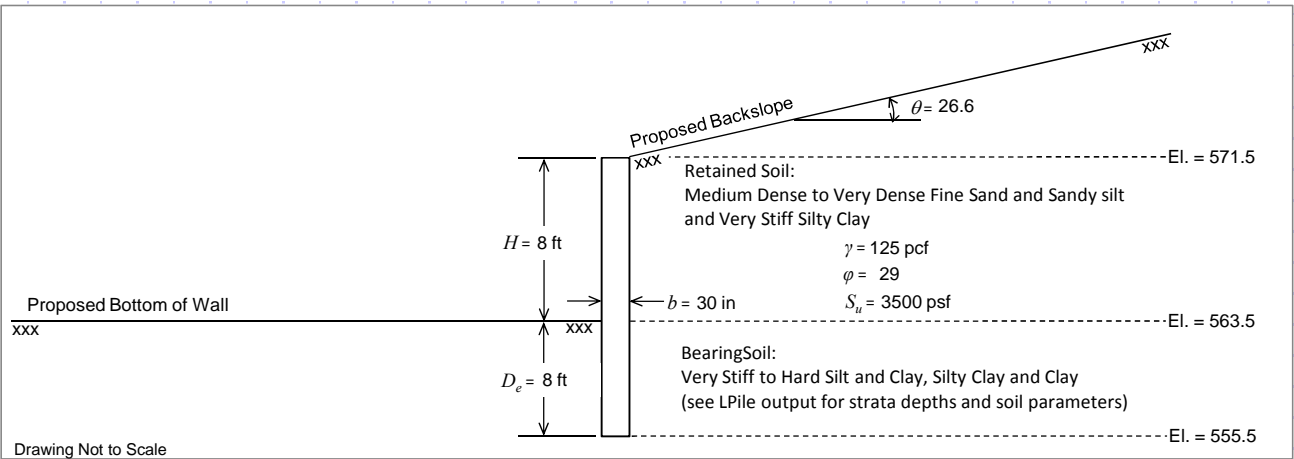


Unconfined Compression Test



APPENDIX VI

**PILE AND LAGGING RETAINING WALL
CALCULATIONS**



Retaining Wall and Soil Parameters

Retaining Wall Height, (H) =	8.0 ft
Soil Friction Angle, (phi') =	29 degrees
Soil Total Unit Weight, (gamma) =	125 pcf
Soil Undrained Shear Strength, (su) =	3500 psf
Backslope Angle, (theta) =	26.6 degrees
Embedment Depth, (Dc) =	8 ft
Shaft Spacing, (S) =	8.0 ft O.C.
Shaft Diameter, (b) =	30 in

Rankine Earth Pressures

$$K_a = \cos \beta \frac{\cos \beta - \sqrt{\cos^2 \beta - \cos^2 \phi}}{\cos \beta + \sqrt{\cos^2 \beta - \cos^2 \phi}}$$

$$K_a = 0.5848$$

$$K_p = \cos \beta \frac{\cos \beta + \sqrt{\cos^2 \beta - \cos^2 \phi}}{\cos \beta - \sqrt{\cos^2 \beta - \cos^2 \phi}}$$

$$K_p = 1.3679$$

LRFD Load Factors

	EH	LS
Strength I	1.50	1.75
Service I	1.00	1.00

(AASHTO LRFD BDM Tab. 3.4.1-1, 3.4.1-2 - Active Earth Pressure)

p-y Reduction Factor

S/b = 3.20
beta_a = 1.0000

Structural Element Properties

Section Type: **W 18x86**

E = 29,000 ksi	d = 18.4 in	I_x = 1530 in ⁴	Z_x = 186 in ³
A_s = 25.3 in ²	t_w = 0.425 in	I_x = 191.3 in ⁴ per ft	Z_x = 23.3 in ³ per ft
f_y = 50 ksi	t_f = 0.680 in	r_s = 7.77 in	T = 15.1 in
			S = 166.0 in ³

Lateral Loading of Cantilever Portion of Wall Retaining Soil - (Loading Case - Service I and Strength I)



Note: Required embedment and determination of structural capacity and allowable deflection at the top of the wall determined using LPile software. Loading conditions and material parameters used in the analysis are provided on this data page.

$$P_{EH} = \gamma H S K_a \gamma_{EH}$$

$$P_{EH} = (125 \text{ pcf})(8.0 \text{ ft})(8 \text{ ft O.C.})(0.585)(1.00) \quad \text{(Service I)}$$

$$= (125 \text{ pcf})(8.0 \text{ ft})(8 \text{ ft O.C.})(0.585)(1.50) \quad \text{(Strength I)}$$

$$P_{EH} = 4678.7 \text{ lb/ft} \quad \text{(Service I)}$$

$$= 7018.1 \text{ lb/ft} \quad \text{(Strength I)}$$

Check Deflection - (Loading Case - Service I)

$$\left(\frac{\delta_h}{H}\right) \cdot 100\% < 1.0\% \quad \longrightarrow \quad \delta_h = 0.161 \text{ in (Determined from LPile)} \quad \longrightarrow \quad 0.17\% < 1.0\% \quad \text{OK}$$

Capacity Verification - (Loading Case - Strength I)

phi_f = 1.00 phi_v = 1.00 C = 1.00

Maximum Bending Moment, M_u = 104.0 kip-ft per section (Determined from LPile analysis)

Maximum Shear Force, V_u = 34.2 kip per section (Determined from LPile analysis)

Factored Flexural Resistance, phi_f M_n = 775.0 kip-ft per section -> M_u < phi_f M_n -> 104.0 kip-ft < 775.0 kip-ft **OK**

Factored Shear Resistance, phi_v V_n = 226.5 kip per section -> V_u < phi_v V_n -> 34.2 kip < 226.5 kip **OK**

$$S_{Req} = M_u \times \left(\frac{12}{50 \text{ ksi}}\right) = (104.0 \text{ kip-ft})(12 \text{ in}) / (50 \text{ ksi}) = 25.0 \text{ in}^3 \quad \longrightarrow \quad S_{Req} < S_{Section} \quad \longrightarrow \quad 25.0 \text{ in}^3 < 166.0 \text{ in}^3 \quad \text{OK}$$

LPILE Plus for Windows, Version 5.0 (5.0.39)

Analysis of Individual Piles and Drilled Shafts
Subjected to Lateral Loading Using the p-y Method

(c) 1985-2007 by Ensoft, Inc.
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This program is licensed to:

Path to file locations: J:\GEOTECH\Projects\2010\B-10-020 HAM-75-7.85\HAM-75-7.85 PID 77889 -
Mainline\Analysis\Retaining Wall U\B-025 - Pile and Lagging - 8.0 ft Wall Ht\
Name of input data file: B-025 - Pile and Lagging - 8.0 ft Wall Ht.lpd
Name of output file: B-025 - Pile and Lagging - 8.0 ft Wall Ht.lpo
Name of plot output file: B-025 - Pile and Lagging - 8.0 ft Wall Ht.lpp
Name of runtime file: B-025 - Pile and Lagging - 8.0 ft Wall Ht.lpr

Time and Date of Analysis

Date: August 8, 2013 Time: 15:42:04

Problem Title

HAM-75-7.85 - Retaining Wall U - B-025-0-11 - 8.0 ft Wall Ht - Service

Program Options

Units Used in Computations - US Customary Units: Inches, Pounds

Basic Program Options:

Analysis Type 1:

- Computation of Lateral Pile Response Using User-specified Constant EI

Computation Options:

- Only internally-generated p-y curves used in analysis
- Analysis uses p-y multipliers for group action
- Analysis assumes no shear resistance at pile tip
- Analysis includes automatic computation of pile-top deflection vs. pile embedment length
- No computation of foundation stiffness matrix elements
- Output pile response for full length of pile
- Analysis assumes no soil movements acting on pile
- No additional p-y curves to be computed at user-specified depths

Solution Control Parameters:

- Number of pile increments = 100
- Maximum number of iterations allowed = 100
- Deflection tolerance for convergence = 1.0000E-05 in
- Maximum allowable deflection = 1.0000E+02 in

Printing Options:

- Values of pile-head deflection, bending moment, shear force, and soil reaction are printed for full length of pile.
- Printing Increment (spacing of output points) = 1

Pile Structural Properties and Geometry

Pile Length = 288.00 in

B-025 - Pile and Lagging - 8.0 ft Wall Ht. Ipo

Depth of ground surface below top of pile = 96.00 in

Slope angle of ground surface = .00 deg.

Structural properties of pile defined using 4 points

Point	Depth X in	Pile Diameter in	Moment of Inertia in**4	Pile Area Sq. in	Modulus of Elasticity lbs/Sq. in
1	0.0000	18.40000000	1530.0000	25.3000	29000000.
2	96.0000	18.40000000	1530.0000	25.3000	29000000.
3	96.0000	30.00000000	39761.0000	706.9000	3604997.
4	288.0000	30.00000000	39761.0000	706.9000	3604997.

Soil and Rock Layering Information

The soil profile is modelled using 3 layers

Layer 1 is stiff clay without free water
 Distance from top of pile to top of layer = 96.000 in
 Distance from top of pile to bottom of layer = 180.000 in

Layer 2 is stiff clay without free water
 Distance from top of pile to top of layer = 180.000 in
 Distance from top of pile to bottom of layer = 348.000 in

Layer 3 is stiff clay without free water
 Distance from top of pile to top of layer = 348.000 in
 Distance from top of pile to bottom of layer = 444.000 in

(Depth of lowest layer extends 156.00 in below pile tip)

Effective Unit Weight of Soil vs. Depth

Effective unit weight of soil with depth defined using 6 points

Point No.	Depth X in	Eff. Unit Weight lbs/in**3
1	96.00	.07200
2	180.00	.07200
3	180.00	.06900
4	348.00	.06900
5	348.00	.07200
6	444.00	.07200

Shear Strength of Soils

Shear strength parameters with depth defined using 6 points

Point No.	Depth X in	Cohesion c lbs/in**2	Angle of Friction Deg.	E50 or k _{rm}	RQD %
1	96.000	27.80000	.00	.00400	.0
2	180.000	27.80000	.00	.00400	.0
3	180.000	19.10000	.00	.00600	.0
4	348.000	19.10000	.00	.00600	.0
5	348.000	27.80000	.00	.00400	.0
6	444.000	27.80000	.00	.00400	.0

Notes:

- (1) Cohesion = uniaxial compressive strength for rock materials.
- (2) Values of E50 are reported for clay strata.
- (3) Default values will be generated for E50 when input values are 0.
- (4) RQD and k_{rm} are reported only for weak rock strata.

 p-y Modification Factors

Distribution of p-y multipliers with depth defined using 2 points

Point No.	Depth X in	p-mult	y-mult
1	96.000	1.0000	1.0000
2	550.000	1.0000	1.0000

 Loading Type

Static loading criteria was used for computation of p-y curves.

 Distributed Lateral Loading

Distributed lateral load intensity defined using 2 points

Point No.	Depth X in	Dist. Load lbs/in
1	.000	.00000
2	96.000	389.90000

 Pile-head Loading and Pile-head Fixity Conditions

Number of loads specified = 1

Load Case Number 1

Pile-head boundary conditions are Shear and Moment (BC Type 1)

Shear force at pile head = .000 lbs
 Bending moment at pile head = .000 in-lbs
 Axial load at pile head = .000 lbs

(Zero moment at pile head for this load indicates a free-head condition)

 Computed Values of Load Distribution and Deflection
 for Lateral Loading for Load Case Number 1

Pile-head boundary conditions are Shear and Moment (BC Type 1)

Specified shear force at pile head = .000 lbs
 Specified moment at pile head = .000 in-lbs
 Specified axial load at pile head = .000 lbs

(Zero moment for this load indicates free-head conditions)

Depth X in	Deflect. y in	Moment M lbs-in	Shear V lbs	Slope S Rad.	Total Stress lbs/in**2	Soil Res. p lbs/in	Es*h F/L lbs/in
0.000	.085247	-2.8953E-06	-1.2888E-08	-.0007713	1.7409E-08	0.0000	0.0000
2.880	.083026	6.0637	18.9491	-.0007713	.0364616	0.0000	0.0000
5.760	.080804	109.1470	69.4802	-.0007712	.6563090	0.0000	0.0000
8.640	.078583	406.2696	153.6986	-.0007712	2.4429	0.0000	0.0000
11.520	.076362	994.4509	271.6043	-.0007712	5.9797	0.0000	0.0000
14.400	.074141	1970.7106	423.1975	-.0007711	11.8500	0.0000	0.0000

B-025 - Pile and Lagging - 8.0 ft Wall Ht. I po									
17.280	.071921	3432.0682	608.4779	-	0007709	20.6373	0.0000	0.0000	0.0000
20.160	.069701	5475.5435	827.4458	-	0007706	32.9248	0.0000	0.0000	0.0000
23.040	.067482	8198.1559	1080.1010	-	0007702	49.2961	0.0000	0.0000	0.0000
25.920	.065265	11696.9251	1366.4435	-	0007695	70.3345	0.0000	0.0000	0.0000
28.800	.063049	16068.8707	1686.4735	-	0007686	96.6233	0.0000	0.0000	0.0000
31.680	.060837	21411.0123	2040.1907	-	0007674	128.7460	0.0000	0.0000	0.0000
34.560	.058629	27820.3694	2427.5954	-	0007658	167.2859	0.0000	0.0000	0.0000
37.440	.056426	35393.9617	2848.6874	-	0007638	212.8264	0.0000	0.0000	0.0000
40.320	.054230	44228.8087	3303.4667	-	0007612	265.9510	0.0000	0.0000	0.0000
43.200	.052042	54421.9301	3791.9335	-	0007580	327.2430	0.0000	0.0000	0.0000
46.080	.049864	66070.3454	4314.0875	-	0007541	397.2857	0.0000	0.0000	0.0000
48.960	.047698	79271.0743	4869.9290	-	0007494	476.6627	0.0000	0.0000	0.0000
51.840	.045547	94121.1363	5459.4578	-	0007437	565.9572	0.0000	0.0000	0.0000
54.720	.043414	110718.	6082.6739	-	0007371	665.7526	0.0000	0.0000	0.0000
57.600	.041302	129157.	6739.5775	-	0007293	776.6324	0.0000	0.0000	0.0000
60.480	.039214	149538.	7430.1683	-	0007203	899.1798	0.0000	0.0000	0.0000
63.360	.037153	171955.	8154.4466	-	0007098	1033.9784	0.0000	0.0000	0.0000
66.240	.035125	196507.	8912.4122	-	0006979	1181.6115	0.0000	0.0000	0.0000
69.120	.033134	223291.	9704.0651	-	0006842	1342.6624	0.0000	0.0000	0.0000
72.000	.031184	252403.	10529.4055	-	0006688	1517.7146	0.0000	0.0000	0.0000
74.880	.029281	283940.	11388.4331	-	0006514	1707.3515	0.0000	0.0000	0.0000
77.760	.027432	318000.	12281.1482	-	0006319	1912.1564	0.0000	0.0000	0.0000
80.640	.025642	354679.	13207.5506	-	0006100	2132.7127	0.0000	0.0000	0.0000
83.520	.023918	394075.	14167.6403	-	0005857	2369.6038	0.0000	0.0000	0.0000
86.400	.022268	436285.	15161.4175	-	0005588	2623.4131	0.0000	0.0000	0.0000
89.280	.020700	481405.	16188.8819	-	0005290	2894.7239	0.0000	0.0000	0.0000
92.160	.019221	529533.	17250.0338	-	0004962	3184.1198	0.0000	0.0000	0.0000
95.040	.017842	580765.	18251.0630	-	0004601	3492.1839	0.0000	0.0000	0.0000
97.920	.016571	634659.	17829.1362	-	0004349	239.4277	-613.8599	106690.	115131.
100.800	.015336	683461.	16062.3322	-	0004217	257.8385	-613.0873	115131.	124545.
103.680	.014142	727178.	14298.8503	-	0004075	274.3309	-611.5529	124545.	135083.
106.560	.012989	765823.	12540.9146	-	0003925	288.9097	-609.2357	135083.	146926.
109.440	.011881	799414.	10790.8123	-	0003768	301.5821	-606.1131	146926.	160297.
112.320	.010819	827978.	9050.8984	-	0003604	312.3580	-602.1604	160297.	175464.
115.200	.009805	851547.	7323.6027	-	0003436	321.2496	-597.3506	175464.	192759.
118.080	.008840	870162.	5611.4369	-	0003263	328.2720	-591.6535	192759.	212595.
120.960	.007925	883869.	3917.0049	-	0003086	333.4431	-585.0353	212595.	235495.
123.840	.007062	892724.	2243.0156	-	0002908	336.7836	-577.4573	235495.	262121.
126.720	.006250	896789.	592.2981	-	0002728	338.3172	-568.8743	262121.	293335.
129.600	.005491	896135.	-1032.1768	-	0002548	338.0707	-559.2332	293335.	330273.
132.480	.004783	890843.	-2627.2689	-	0002369	336.0743	-548.4697	330273.	374458.
135.360	.004126	881002.	-4189.6316	-	0002191	332.3617	-536.5044	374458.	427991.
138.240	.003521	866711.	-5715.6599	-	0002015	326.9703	-523.2374	427991.	493845.
141.120	.002966	848080.	-7201.4173	-	0001843	319.9416	-508.5386	493845.	576385.
144.000	.002460	825231.	-8642.5292	-	0001675	311.3217	-492.2336	576385.	682296.
146.880	.002001	798299.	-10034.0208	-	0001512	301.1615	-474.0800	682296.	822414.
149.760	.001589	767435.	-11370.0598	-	0001354	289.5179	-453.7248	822414.	1015653.
152.640	.001221	732807.	-12643.5229	-	0001203	276.4546	-430.6245	1015653.	1298635.
155.520	.000896	694608.	-13845.2027	-	0001060	262.0438	-403.8754	1298635.	1754035.
158.400	.000610	653059.	-14962.1755	-9.	2471E-05	246.3692	-371.8002	1754035.	1801962.
161.280	.000363	608426.	-15824.6679	-7.	9798E-05	229.5312	-227.1528	1801962.	1825437.
164.160	.000151	561909.	-16289.4381	-6.	8040E-05	211.9825	-95.6043	1825437.	1848912.
167.040	-2.89E-05	514599.	-16400.4258	-5.	7225E-05	194.1345	18.5295	1848912.	1872387.
169.920	-	467442.	-16206.3677	-4.	7360E-05	176.3446	116.2331	1872387.	1895862.
172.800	-	421250.	-15753.0442	-3.	8432E-05	158.9184	198.5749	1895862.	1919337.
175.680	-	376705.	-15083.0850	-3.	0415E-05	142.1135	266.6746	1919337.	1942812.
178.560	-	334372.	-14235.8615	-2.	3272E-05	126.1431	321.6751	1942812.	1390408.
181.440	-	294706.	-13401.2747	-1.	6952E-05	111.1792	257.8990	1390408.	1405720.
184.320	-	257180.	-12626.1140	-1.	1408E-05	97.0223	280.4070	1405720.	1421035.
187.200	-	221980.	-11796.0863	-6.	5939E-06	83.7429	296.0010	1421035.	1414443.
190.080	-	189235.	-10936.6925	-2.	4627E-06	71.3896	300.8002	1414443.	1426654.
192.960	-	158985.	-10065.4943	1.	0355E-06	59.9776	304.1985	1426654.	1455166.
195.840	-	131258.	-9186.1651	3.	9514E-06	49.5175	306.4468	1455166.	1482312.
198.720	-	106072.	-8306.6151	6.	3356E-06	40.0162	304.3518	1482312.	1497635.
201.600	-	83411.4823	-7441.5128	8.	2392E-06	31.4673	296.4136	1497635.	1512960.
204.480	-	63209.2120	-6603.2501	9.	7122E-06	23.8459	285.7133	1512960.	1528285.
207.360	-	45376.7620	-5798.9996	1.	803E-05	17.1186	272.7940	1528285.	1543612.
210.240	-	29806.9745	-5034.4397	1.	1558E-05	11.2448	258.1504	1543612.	1558940.
213.120	-	16378.3895	-4313.8946	1.	2022E-05	6.1788	242.2282	1558940.	1574269.
216.000	-	9958.9417	-3640.4747	1.	2237E-05	1.8708	225.4245	1574269.	1589599.
218.880	-	-4590.7450	-3016.2153	1.	2240E-05	1.7319	208.0890	1589599.	1604929.
221.760	-	-12414.4584	-2442.2113	1.	2070E-05	4.6834	190.5249	1604929.	1620260.
224.640	-	-18657.8823	-1918.7483	1.	1757E-05	7.0388	172.9911	1620260.	1635592.
227.520	-	-23466.4486	-1445.4268	1.	1334E-05	8.8528	155.7043	1635592.	1650925.
230.400	-	-26983.5409	-1021.2812	1.	0827E-05	10.1797	138.8412	1650925.	1666258.
233.280	-	-29349.0285	-644.8906	1.	0261E-05	11.0720	122.5412	1666258.	1681592.
236.160	-	-30698.1105	-314.4821	9.	6582E-06	11.5810	106.9091	1681592.	1696927.
239.040	-	-31160.4456	-28.0271	9.	0368E-06	11.7554	92.0180	1696927.	1712262.
241.920	-	-30859.5464	216.6726	8.	4137E-06	11.6419	77.9123	1712262.	

B-025 - Pile and Lagging - 8.0 ft Wall Ht. Ipo									
244.800	-	.000108	-29912.4115	421.9049	7.8032E-06	11.2846	64.6102	1727597.	
247.680	-8.61E-05		-28429.3742	589.9776	7.2171E-06	10.7251	52.1070	1742933.	
250.560	-6.61E-05		-26514.1404	723.1562	6.6651E-06	10.0026	40.3781	1758269.	
253.440	-4.77E-05		-24263.9944	823.6100	6.1550E-06	9.1537	29.3815	1773606.	
256.320	-3.07E-05		-21770.1467	893.3667	5.6925E-06	8.2129	19.0607	1788943.	
259.200	-1.49E-05		-19118.2021	934.2750	5.2817E-06	7.2124	9.3478	1804281.	
262.080	-2.63E-07		-16388.7229	947.9749	4.9250E-06	6.1827	.1659992	1819619.	
264.960	1.34E-05		-13657.8668	935.8764	4.6232E-06	5.1525	-8.5677	1834957.	
267.840	2.64E-05		-10998.0748	899.1457	4.3755E-06	4.1491	-16.9397	1850296.	
270.720	3.87E-05		-8478.7877	838.6991	4.1798E-06	3.1987	-25.0371	1865635.	
273.600	5.04E-05		-6167.1682	755.2051	4.0327E-06	2.3266	-32.9449	1880974.	
276.480	6.19E-05		-4128.8065	649.0942	3.9292E-06	1.5576	-40.7433	1896313.	
279.360	7.31E-05		-2428.3856	520.5768	3.8634E-06	.9161184	-48.5049	1911653.	
282.240	8.41E-05		-1130.2839	369.6695	3.8276E-06	.4264042	-56.2918	1926993.	
285.120	9.51E-05		-299.0891	196.2298	3.8133E-06	.1128326	-64.1524	1942333.	
288.000	.000106	0.0000	0.0000	0.0000	3.8103E-06	0.0000	-72.1183	978837.	

Output Veri fication:

Computed forces and moments are withi n speci fied convergence l i m i t s.

Output Summary for Load Case No. 1:

Pile-head deflection = .08524689 in
 Computed slope at pile head = -.00077125
 Maximum bending moment = 896788.60533 lbs-in
 Maximum shear force = 18251.06304 lbs
 Depth of maximum bending moment = 126.72000 in
 Depth of maximum shear force = 95.04000000 in
 Number of iterations = 13
 Number of zero deflection points = 2

 Summary of Pile Response(s)

Defini tion of Symbols for Pile-Head Loading Condi ti ons:

Type 1 = Shear and Moment, y = pile-head displacement in
 Type 2 = Shear and Slope, M = Pile-head Moment lbs-in
 Type 3 = Shear and Rot. Stiffness, V = Pile-head Shear Force lbs
 Type 4 = Deflection and Moment, S = Pile-head Slope, radians
 Type 5 = Deflection and Slope, R = Rot. Stiffness of Pile-head in-lbs/rad

Load Type	Pile-Head Condition 1	Pile-Head Condition 2	Axial Load lbs	Pile-Head Deflection in	Maximum Moment in-lbs	Maximum Shear lbs
1	V=	0.000 M=	0.000	.0852469	896789.	18251.0630

 Pile-head Deflection vs. Pile Length

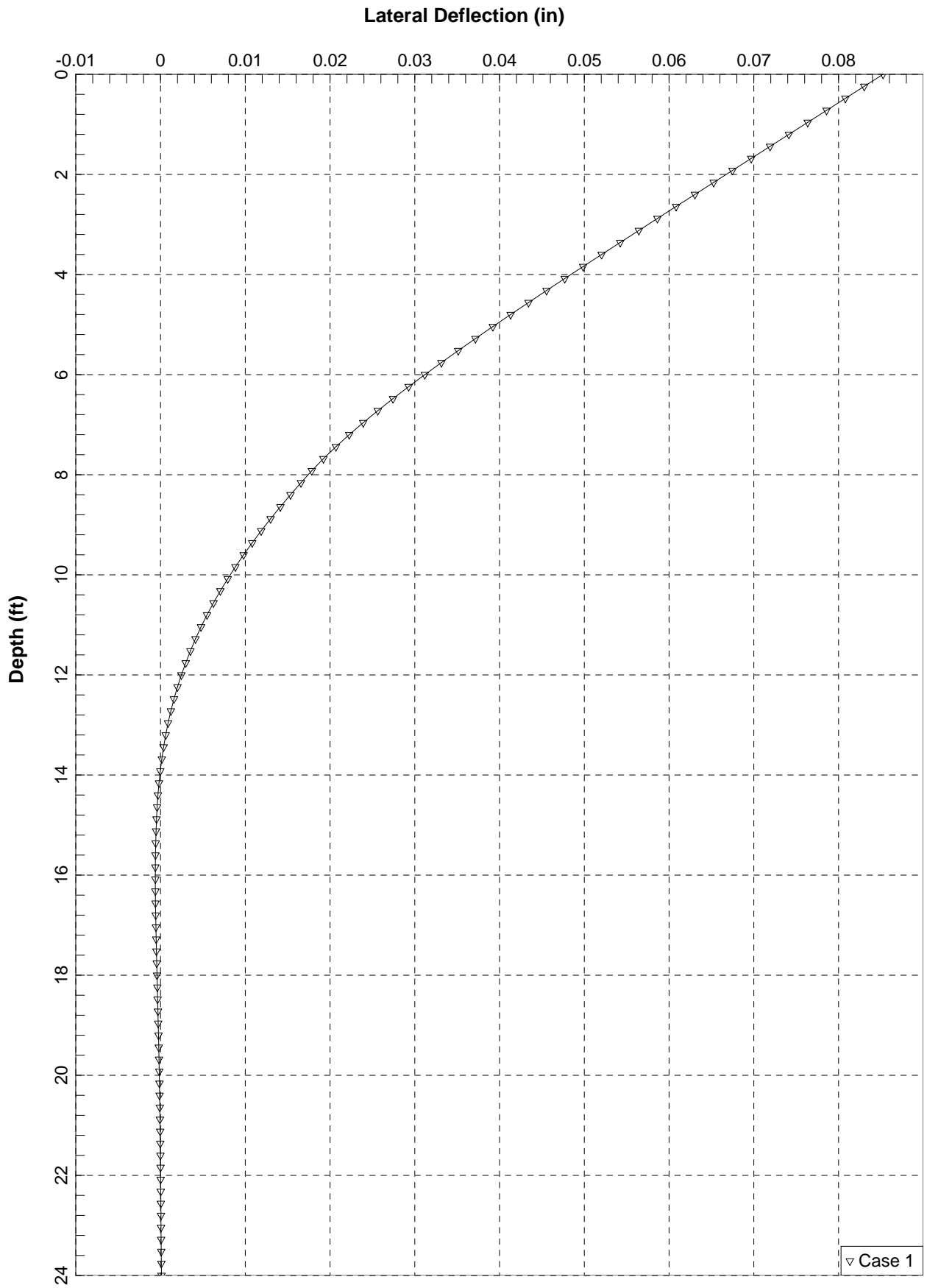
Boundary Condi tion Type 1, Shear and Moment

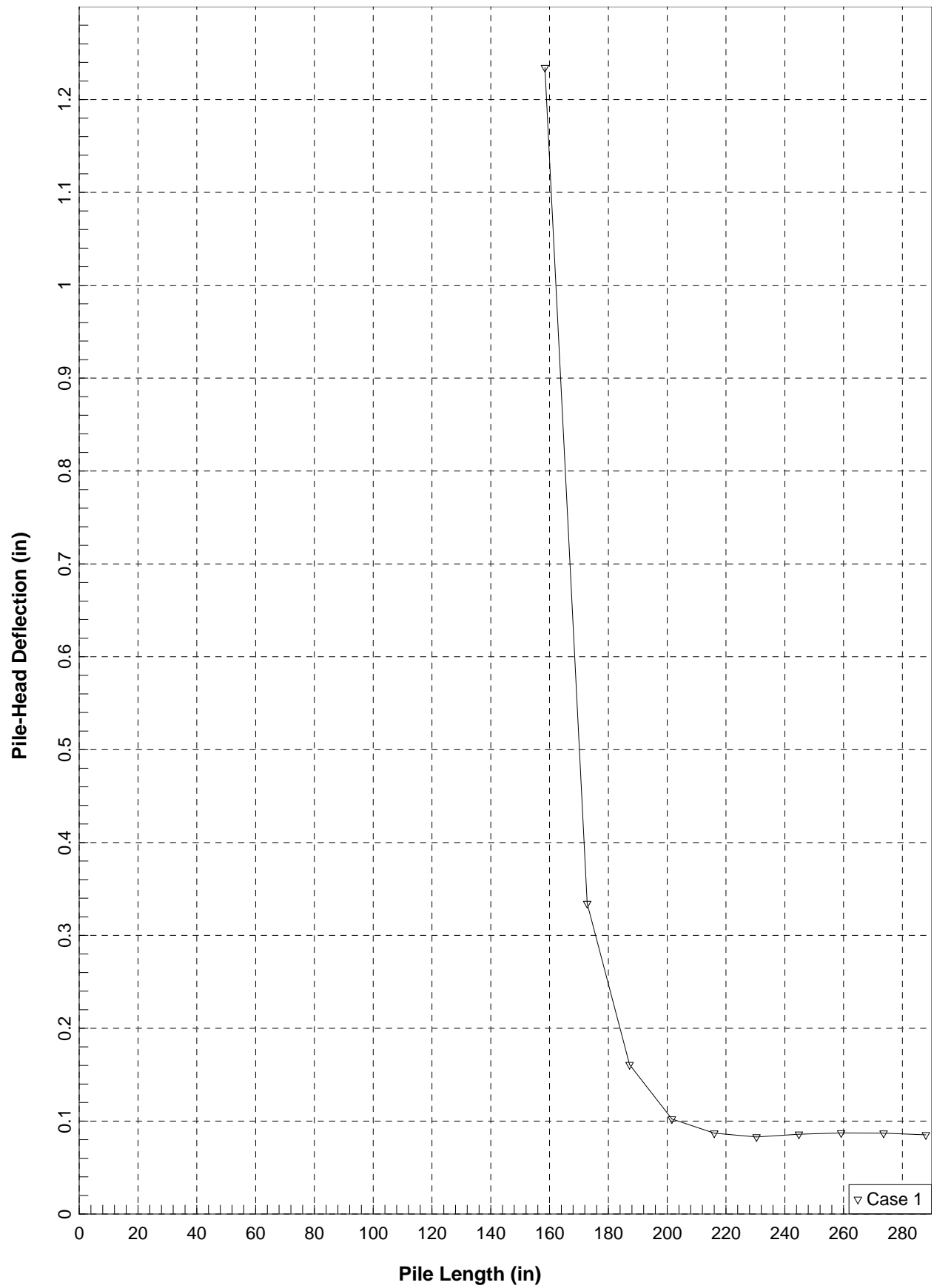
Shear = 0. lbs
 Moment = 0. in-lbs
 Axial Load = 0. lbs

Pile Length in	Pile Head Deflection in	Maximum Moment in-lbs	Maximum Shear lbs
288.000	.08524689	896788.60533	18251.06304
273.600	.08706719	907167.68906	18402.44560
259.200	.08730310	907837.79657	18444.09158
244.800	.08591012	900198.47764	18375.24302
230.400	.08301521	882939.61347	18122.45205
216.000	.08700275	885399.45578	18320.54313
201.600	.10238747	855943.63685	-20184.29942

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187.200 .16082699 829523.80598 -22602.59589
172.800 .33427926 780487.44272 -24263.02957
158.400 1.23431767 730908.10464 -27032.78726

The analysis ended normally.





LPILE Plus for Windows, Version 5.0 (5.0.39)

Analysis of Individual Piles and Drilled Shafts
Subjected to Lateral Loading Using the p-y Method

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This program is licensed to:

Path to file locations: J:\GEOTECH\Projects\2010\B-10-020 HAM-75-7.85\HAM-75-7.85 PID 77889 -
Mainline\Analysis\Retaining Wall U\B-025 - Pile and Lagging - 8.0 ft Wall Ht\
Name of input data file: B-025 - Pile and Lagging - 8.0 ft Wall Ht.lpd
Name of output file: B-025 - Pile and Lagging - 8.0 ft Wall Ht.lpo
Name of plot output file: B-025 - Pile and Lagging - 8.0 ft Wall Ht.lpp
Name of runtime file: B-025 - Pile and Lagging - 8.0 ft Wall Ht.lpr

Time and Date of Analysis

Date: August 8, 2013 Time: 15:45:41

Problem Title

HAM-75-7.85 - Retaining Wall U - B-025-0-11 - 8.0 ft Wall Ht - Service

Program Options

Units Used in Computations - US Customary Units: Inches, Pounds

Basic Program Options:

Analysis Type 1:

- Computation of Lateral Pile Response Using User-specified Constant EI

Computation Options:

- Only internally-generated p-y curves used in analysis
- Analysis uses p-y multipliers for group action
- Analysis assumes no shear resistance at pile tip
- Analysis includes automatic computation of pile-top deflection vs. pile embedment length
- No computation of foundation stiffness matrix elements
- Output pile response for full length of pile
- Analysis assumes no soil movements acting on pile
- No additional p-y curves to be computed at user-specified depths

Solution Control Parameters:

- Number of pile increments = 100
- Maximum number of iterations allowed = 100
- Deflection tolerance for convergence = 1.0000E-05 in
- Maximum allowable deflection = 1.0000E+02 in

Printing Options:

- Values of pile-head deflection, bending moment, shear force, and soil reaction are printed for full length of pile.
- Printing Increment (spacing of output points) = 1

Pile Structural Properties and Geometry

Pile Length = 288.00 in

B-025 - Pile and Lagging - 8.0 ft Wall Ht. Ipo

Depth of ground surface below top of pile = 96.00 in

Slope angle of ground surface = .00 deg.

Structural properties of pile defined using 4 points

Point	Depth X in	Pile Diameter in	Moment of Inertia in**4	Pile Area Sq. in	Modulus of Elasticity lbs/Sq. in
1	0.0000	18.40000000	1530.0000	25.3000	29000000.
2	96.0000	18.40000000	1530.0000	25.3000	29000000.
3	96.0000	30.00000000	39761.0000	706.9000	3604997.
4	288.0000	30.00000000	39761.0000	706.9000	3604997.

Soil and Rock Layering Information

The soil profile is modelled using 3 layers

Layer 1 is stiff clay without free water
 Distance from top of pile to top of layer = 96.000 in
 Distance from top of pile to bottom of layer = 180.000 in

Layer 2 is stiff clay without free water
 Distance from top of pile to top of layer = 180.000 in
 Distance from top of pile to bottom of layer = 348.000 in

Layer 3 is stiff clay without free water
 Distance from top of pile to top of layer = 348.000 in
 Distance from top of pile to bottom of layer = 444.000 in

(Depth of lowest layer extends 156.00 in below pile tip)

Effective Unit Weight of Soil vs. Depth

Effective unit weight of soil with depth defined using 6 points

Point No.	Depth X in	Eff. Unit Weight lbs/in**3
1	96.00	.07200
2	180.00	.07200
3	180.00	.06900
4	348.00	.06900
5	348.00	.07200
6	444.00	.07200

Shear Strength of Soils

Shear strength parameters with depth defined using 6 points

Point No.	Depth X in	Cohesion c lbs/in**2	Angle of Friction Deg.	E50 or k _{rm}	RQD %
1	96.000	27.80000	.00	.00400	.0
2	180.000	27.80000	.00	.00400	.0
3	180.000	19.10000	.00	.00600	.0
4	348.000	19.10000	.00	.00600	.0
5	348.000	27.80000	.00	.00400	.0
6	444.000	27.80000	.00	.00400	.0

Notes:

- (1) Cohesion = uniaxial compressive strength for rock materials.
- (2) Values of E50 are reported for clay strata.
- (3) Default values will be generated for E50 when input values are 0.
- (4) RQD and k_{rm} are reported only for weak rock strata.

 p-y Modification Factors

Distribution of p-y multipliers with depth defined using 2 points

Point No.	Depth X in	p-mult	y-mult
1	96.000	1.0000	1.0000
2	550.000	1.0000	1.0000

 Loading Type

Static loading criteria was used for computation of p-y curves.

 Distributed Lateral Loading

Distributed lateral load intensity defined using 2 points

Point No.	Depth X in	Dist. Load lbs/in
1	.000	.00000
2	96.000	584.80000

 Pile-head Loading and Pile-head Fixity Conditions

Number of loads specified = 1

Load Case Number 1

Pile-head boundary conditions are Shear and Moment (BC Type 1)

Shear force at pile head = .000 lbs
 Bending moment at pile head = .000 in-lbs
 Axial load at pile head = .000 lbs

(Zero moment at pile head for this load indicates a free-head condition)

 Computed Values of Load Distribution and Deflection
 for Lateral Loading for Load Case Number 1

Pile-head boundary conditions are Shear and Moment (BC Type 1)

Specified shear force at pile head = .000 lbs
 Specified moment at pile head = .000 in-lbs
 Specified axial load at pile head = .000 lbs

(Zero moment for this load indicates free-head conditions)

Depth X in	Deflect. y in	Moment M lbs-in	Shear V lbs	Slope S Rad.	Total Stress lbs/in**2	Soil Res. p lbs/in	Es*h F/L lbs/in
0.000	.154564	-2.2271E-06	2.5777E-08	-.0013135	1.3392E-08	0.0000	0.0000
2.880	.150781	9.0948	28.4213	-.0013135	.0546878	0.0000	0.0000
5.760	.146998	163.7066	104.2114	-.0013135	.9843794	0.0000	0.0000
8.640	.143215	609.3522	230.5282	-.0013135	3.6641	0.0000	0.0000
11.520	.139432	1491.5488	407.3717	-.0013134	8.9688	0.0000	0.0000
14.400	.135650	2955.8131	634.7419	-.0013133	17.7735	0.0000	0.0000

B-025 - Pile and Lagging - 8.0 ft Wall Ht. I po							
17.280	.131868	5147.6622	912.6389	-	0013130	30.9533	0.0000
20.160	.128087	8212.6131	1241.0626	-	0013126	49.3830	0.0000
23.040	.124307	12296.1826	1620.0130	-	0013119	73.9378	0.0000
25.920	.120530	17543.8877	2049.4901	-	0013109	105.4927	0.0000
28.800	.116756	24101.2454	2529.4939	-	0013096	144.9225	0.0000
31.680	.112987	32113.7727	3060.0245	-	0013078	193.1024	0.0000
34.560	.109223	41726.9864	3641.0818	-	0013054	250.9074	0.0000
37.440	.105468	53086.4036	4272.6658	-	0013023	319.2124	0.0000
40.320	.101722	66337.5412	4954.7765	-	0012984	398.8924	0.0000
43.200	.097989	81625.9162	5687.4139	-	0012936	490.8225	0.0000
46.080	.094271	99097.0454	6470.5781	-	0012878	595.8777	0.0000
48.960	.090571	118896.	7304.2690	-	0012807	714.9329	0.0000
51.840	.086894	141170.	8188.4866	-	0012722	848.8632	0.0000
54.720	.083243	166062.	9123.2309	-	0012623	998.5435	0.0000
57.600	.079624	193719.	10108.5019	-	0012506	1164.8489	0.0000
60.480	.076040	224287.	11144.2997	-	0012370	1348.6545	0.0000
63.360	.072498	257911.	12230.6242	-	0012214	1550.8350	0.0000
66.240	.069005	294735.	13367.4754	-	0012034	1772.2657	0.0000
69.120	.065566	334907.	14554.8533	-	0011830	2013.8215	0.0000
72.000	.062191	378571.	15792.7579	-	0011599	2276.3773	0.0000
74.880	.058886	425874.	17081.1893	-	0011337	2560.8083	0.0000
77.760	.055660	476959.	18420.1474	-	0011044	2867.9894	0.0000
80.640	.052524	531974.	19809.6322	-	0010717	3198.7955	0.0000
83.520	.049487	591063.	21249.6437	-	0010352	3554.1018	0.0000
86.400	.046561	654372.	22740.1819	-	0009948	3934.7832	0.0000
89.280	.043757	722046.	24281.2469	-	0009502	4341.7147	0.0000
92.160	.041088	794232.	25872.8386	-	0009009	4775.7713	0.0000
95.040	.038568	871074.	27374.2541	-	0008469	5237.8281	0.0000
97.920	.036210	951907.	26992.2554	-	0008091	359.1109	-746.5185
100.800	.033907	1026549.	24840.4809	-	0007892	387.2698	-747.7693
103.680	.031664	1094988.	22686.1873	-	0007679	413.0889	-748.2679
106.560	.029484	1157221.	20531.5673	-	0007453	436.5665	-747.9960
109.440	.027372	1213250.	18378.8683	-	0007214	457.7036	-746.9339
112.320	.025329	1263084.	16230.3953	-	0006966	476.5035	-745.0612
115.200	.023359	1306737.	14088.5149	-	0006707	492.9720	-742.3558
118.080	.021465	1344234.	11955.6593	-	0006441	507.1176	-738.7939
120.960	.019649	1375602.	9834.3324	-	0006168	518.9515	-734.3498
123.840	.017913	1400879.	7727.1156	-	0005889	528.4874	-728.9952
126.720	.016257	1420110.	5636.6763	-	0005606	535.7423	-722.6987
129.600	.014684	1433347.	3565.7778	-	0005319	540.7359	-715.4252
132.480	.013194	1440649.	1517.2913	-	0005030	543.4907	-707.1348
135.360	.011787	1442086.	-505.7884	-	0004741	544.0329	-697.7816
138.240	.010463	1437736.	-2500.3231	-	0004451	542.3917	-687.3119
141.120	.009223	1427684.	-4463.0054	-	0004163	538.5997	-675.6619
144.000	.008065	1412029.	-6390.3250	-	0003878	532.6936	-662.7545
146.880	.006989	1390876.	-8278.5234	-	0003597	524.7137	-648.4944
149.760	.005993	1364344.	-10123.5318	-	0003320	514.7045	-632.7614
152.640	.005077	1332564.	-11920.8836	-	0003049	502.7154	-615.3996
155.520	.004237	1295680.	-13665.5887	-	0002785	488.8006	-596.2011
158.400	.003473	1253851.	-15351.9434	-	0002529	473.0203	-574.8786
161.280	.002781	1207253.	-16973.2341	-	0002281	455.4411	-551.0177
164.160	.002159	1156085.	-18521.2419	-	0002044	436.1377	-523.9877
167.040	.001603	1100571.	-19985.3534	-	0001817	415.1948	-492.7564
169.920	.001112	1040969.	-21350.7694	-	0001602	392.7099	-455.4492
172.800	.000681	977590.	-22594.2020	-	0001399	368.7999	-408.0457
175.680	.000306	910827.	-23475.2512	-	0001210	343.6131	-203.7941
178.560	-1.62E-05	842373.	-23752.9601	-	0001033	317.7886	10.9407
181.440	-	774010.	-23535.9518	-8.	7110E-05	291.9983	139.7595
184.320	-	706806.	-22970.6374	-7.	2233E-05	266.6453	252.8199
187.200	-	641699.	-22162.9198	-5.	8686E-05	242.0835	308.0952
190.080	-	579147.	-21248.5441	-4.	6421E-05	218.4857	326.8880
192.960	-	519307.	-20286.5616	-3.	5386E-05	195.9107	341.1554
195.840	-	462297.	-19288.0847	-2.	5524E-05	174.4033	352.2314
198.720	-	408208.	-18261.2153	-1.	6779E-05	153.9980	360.8724
201.600	-	357112.	-17212.2834	-9.	0907E-06	134.7220	367.5525
204.480	-	309065.	-16146.4780	-2.	3982E-06	116.5960	372.5901
207.360	-	264108.	-15068.2061	3.	3600E-06	99.6359	376.2098
210.240	-	222272.	-13981.3136	8.	2462E-06	83.8531	378.5767
213.120	-	183576.	-12889.2290	1.	2323E-05	69.2548	379.8154
216.000	-	148030.	-11795.0621	1.	5655E-05	55.8450	380.0227
218.880	-	115636.	-10701.6744	1.	8304E-05	43.6243	379.2743
221.760	-	86388.4819	-9611.7320	2.	0333E-05	32.5904	377.6302
224.640	-	60272.8016	-8527.7464	2.	1807E-05	22.7382	375.1376
227.520	-	37268.6626	-7452.1094	2.	2787E-05	14.0598	371.8326
230.400	-	17348.6515	-6387.1242	2.	3335E-05	6.5448	367.7405
233.280	-	478.8271	-5335.0370	2.	3514E-05	1806395	362.8756
236.160	-	-13381.1617	-4298.0716	2.	3385E-05	5.0481	357.2392
239.040	-	-24278.0652	-3289.9755	2.	3006E-05	9.1590	342.8275
241.920	-	-32331.4206	-2354.2956	2.	2438E-05	12.1972	306.9502

B-025 - Pile and Lagging - 8.0 ft Wall Ht.lpo									
244.800	-	.000453	-37838.8080	-1521.3313	2.1733E-05	14.2748	271.4972	1727597.	
247.680	-	.000391	-41094.2889	-789.5400	2.0940E-05	15.5030	236.6911	1742933.	
250.560	-	.000332	-42386.5587	-156.8428	2.0101E-05	15.9905	202.6820	1758269.	
253.440	-	.000275	-41997.7032	379.1766	1.9253E-05	15.8438	169.5537	1773606.	
256.320	-	.000221	-40202.5015	821.0913	1.8428E-05	15.1666	137.3315	1788943.	
259.200	-	.000169	-37268.2173	1171.4730	1.7649E-05	14.0596	105.9891	1804281.	
262.080	-	.000119	-33454.8169	1432.7546	1.6939E-05	12.6210	75.4564	1819619.	
264.960	-7.16E-05		-29015.5508	1607.1151	1.6311E-05	10.9462	45.6272	1834957.	
267.840	-2.55E-05		-24197.8341	1696.3874	1.5777E-05	9.1287	16.3674	1850296.	
270.720	1.93E-05		-19244.3593	1701.9900	1.5340E-05	7.2600	-12.4767	1865635.	
273.600	6.29E-05		-14394.3715	1624.8825	1.5002E-05	5.4303	-41.0701	1880974.	
276.480	.000106		-9885.0360	1465.5466	1.4758E-05	3.7292	-69.5798	1896313.	
279.360	.000148		-5952.8233	1223.9932	1.4599E-05	2.2457	-98.1656	1911653.	
282.240	.000190		-2834.8354	899.7969	1.4511E-05	1.0695	-126.9707	1926993.	
285.120	.000231		-769.9932	492.1589	1.4475E-05	2904831	-156.1112	1942333.	
288.000	.000273		0.0000	0.0000	1.4467E-05	0.0000	-185.6658	978837.	

Output Veri fication:

Computed forces and moments are withi n speci fied convergence l i m i t s.

Output Summary for Load Case No. 1:

Pile-head deflection	=	.15456371	in
Computed slope at pile head	=	-.00131352	
Maximum bending moment	=	1442086.	lbs-in
Maximum shear force	=	27374.25408	lbs
Depth of maximum bending moment	=	135.36000	in
Depth of maximum shear force	=	95.04000000	in
Number of iterations	=	15	
Number of zero deflection points	=	2	

Summary of Pile Response(s)

Defini tion of Symbols for Pile-Head Loading Condi ti ons:

Type 1 = Shear and Moment,	y = pile-head displacement in
Type 2 = Shear and Slope,	M = Pile-head Moment lbs-in
Type 3 = Shear and Rot. Stiffness,	V = Pile-head Shear Force lbs
Type 4 = Deflection and Moment,	S = Pile-head Slope, radians
Type 5 = Deflection and Slope,	R = Rot. Stiffness of Pile-head in-lbs/rad

Load Type	Pile-Head Condition 1	Pile-Head Condition 2	Axial Load lbs	Pile-Head Deflection in	Maximum Moment in-lbs	Maximum Shear lbs		
1	V=	0.000	M=	0.000	0.0000	.1545637	1442086.	27374.2541

Pile-head Deflection vs. Pile Length

Boundary Condi ti on Type 1, Shear and Moment

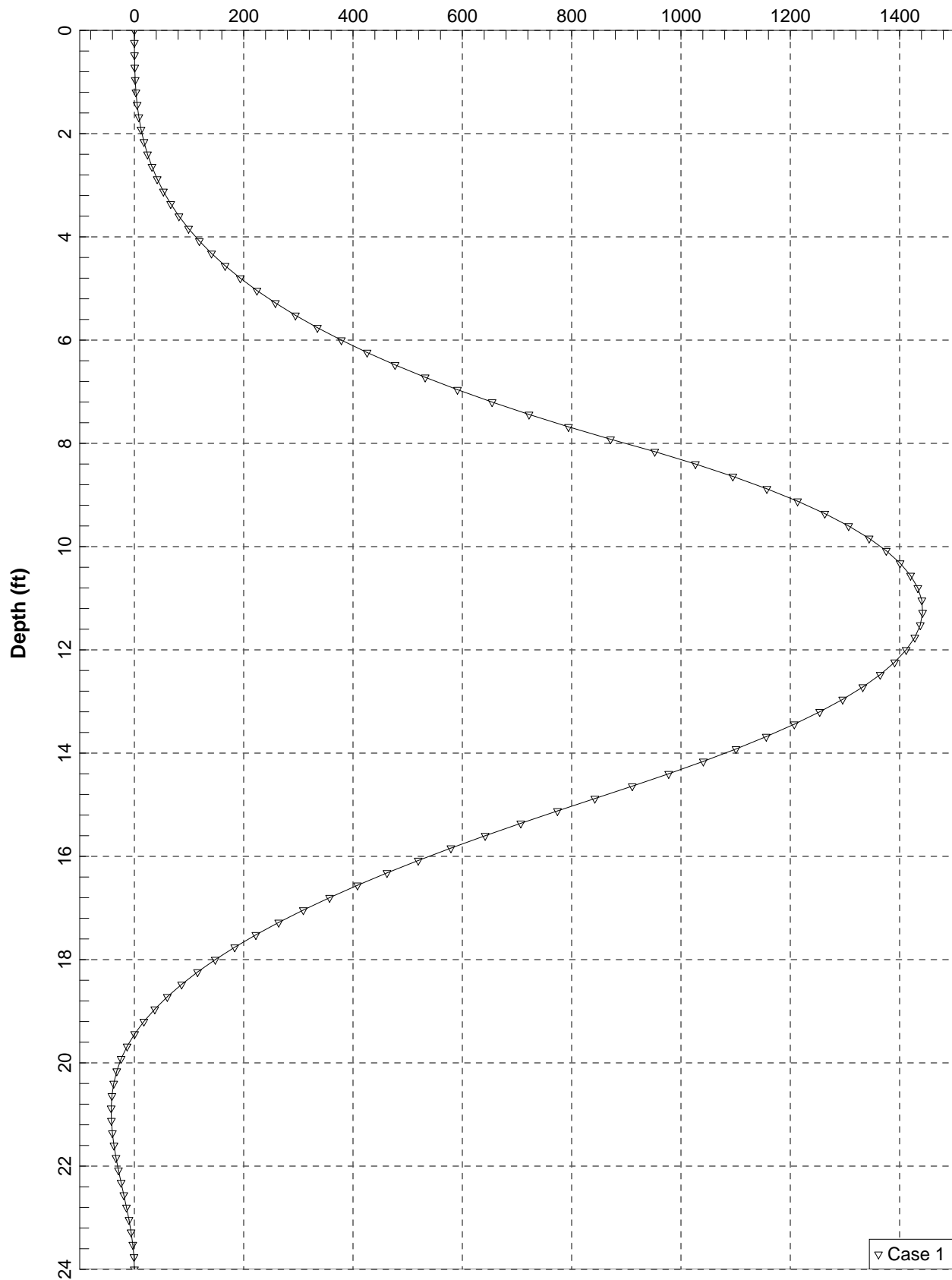
Shear	=	0.	lbs
Moment	=	0.	in-lbs
Axial Load	=	0.	lbs

Pile Length in	Pile Head Deflection in	Maximum Moment in-lbs	Maximum Shear lbs
288.000	.15456371	1442086.	27374.25408
273.600	.15760509	1456709.	27601.30851
259.200	.15792976	1458805.	27663.77214
244.800	.15612598	1446191.	27560.50813
230.400	.16049974	1403935.	27181.35409
216.000	.20567254	1367909.	-28711.47964
201.600	.31347610	1298758.	-31194.42753

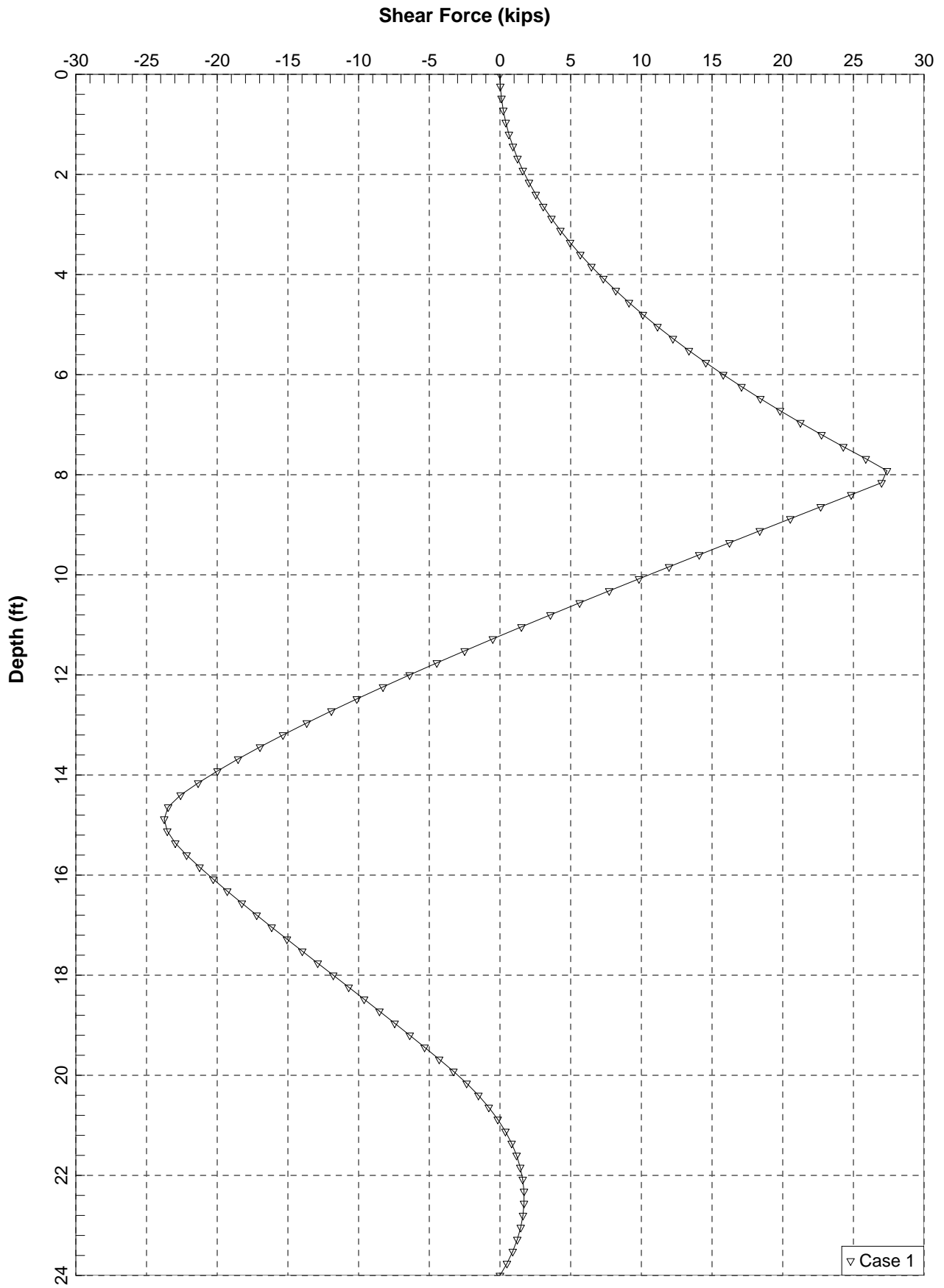
187.200	.62769216	B-025 - Pile and Lagging - 8.0 ft Wall Ht. Ipo
172.800	1.52874812	1248134. -34192.75119
158.400	6.10391618	1171659. -36457.67665
		1096408. -40561.09255

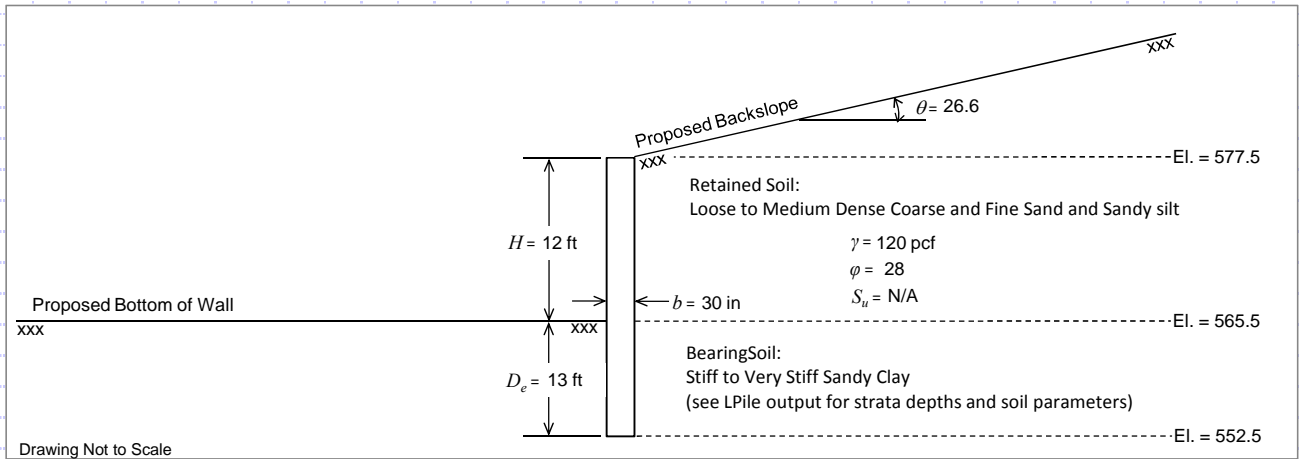
The analysis ended normally.

Bending Moment (in-kips)



▽ Case 1





Retaining Wall and Soil Parameters

Retaining Wall Height, (H) =	12.0 ft
Soil Friction Angle, (ϕ') =	28°
Soil Total Unit Weight, (γ) =	120 pcf
Soil Undrained Shear Strength, (s_u) =	N/A
Backslope Angle, (θ) =	26.6°
Embedment Depth, (D_e) =	13 ft
Shaft Spacing, (S) =	7.0 ft O.C.
Shaft Diameter, (b) =	30 in

Rankine Earth Pressures

$$K_a = \cos \beta \frac{\cos \beta - \sqrt{\cos^2 \beta - \cos^2 \phi}}{\cos \beta + \sqrt{\cos^2 \beta - \cos^2 \phi}}$$

$$K_a = 0.6481$$

$$K_p = \cos \beta \frac{\cos \beta + \sqrt{\cos^2 \beta - \cos^2 \phi}}{\cos \beta - \sqrt{\cos^2 \beta - \cos^2 \phi}}$$

$$K_p = 1.2344$$

LRFD Load Factors

	EH	LS
Strength I	1.50	1.75
Service I	1.00	1.00

(AASHTO LRFD BDM Tab. 3.4.1-1, 3.4.1-2 - Active Earth Pressure)

p-y Reduction Factor

$$S/b = 2.80$$

$$\beta_a = 0.9477$$

Structural Element Properties

Section Type: **W 18x86**

E = 29,000 ksi	d = 18.4 in	I _x = 1530 in ⁴	Z _x = 186 in ³
A _s = 25.3 in ²	t _w = 0.425 in	I _x = 218.6 in ⁴ per ft	Z _x = 26.6 in ³ per ft
f _y = 50 ksi	t _f = 0.680 in	r _s = 7.77 in	T = 15.1 in
			S = 166.0 in ³

Lateral Loading of Cantilever Portion of Wall Retaining Soil - (Loading Case - Service I and Strength I)



Note: Required embedment and determination of structural capacity and allowable deflection at the top of the wall determined using LPILE software. Loading conditions and material parameters used in the analysis are provided on this data page.

$$P_{EH} = \gamma H S K_a \gamma_{EH}$$

$$P_{EH} = (120 \text{ pcf})(12.0 \text{ ft})(7 \text{ ft O.C.})(0.648)(1.00) \quad (\text{Service I})$$

$$= (120 \text{ pcf})(12.0 \text{ ft})(7 \text{ ft O.C.})(0.648)(1.50) \quad (\text{Strength I})$$

$$P_{EH} = 6532.7 \text{ lb/ft} \quad (\text{Service I})$$

$$= 9799.1 \text{ lb/ft} \quad (\text{Strength I})$$

Check Deflection - (Loading Case - Service I)

$$\left(\frac{\delta_h}{H}\right) \cdot 100\% < 1.0\% \quad \longrightarrow \quad \delta_h = 1.440 \text{ in} \quad (\text{Determined from LPILE}) \quad \longrightarrow \quad 1.00\% < 1.0\% \quad \text{OK}$$

Capacity Verification - (Loading Case - Strength I)

$\phi_f = 1.00$ $\phi_v = 1.00$ $C = 1.00$

Maximum Bending Moment, $M_u = 357.6$ kip-ft per section (Determined from LPILE analysis)

Maximum Shear Force, $V_u = 76.6$ kip per section (Determined from LPILE analysis)

Factored Flexural Resistance, $\phi_f M_n = 775.0$ kip-ft per section $\longrightarrow M_u < \phi_f M_n \longrightarrow 357.6 \text{ kip-ft} < 775.0 \text{ kip-ft}$ **OK**

Factored Shear Resistance, $\phi_v V_n = 226.5$ kip per section $\longrightarrow V_u < \phi_v V_n \longrightarrow 76.6 \text{ kip} < 226.5 \text{ kip}$ **OK**

$$S_{Req} = M_u \times \left(\frac{12}{50 \text{ ksi}}\right) = (357.6 \text{ kip-ft})(12 \text{ in}) / (50 \text{ ksi}) = 85.8 \text{ in}^3 \quad \longrightarrow \quad S_{Req} < S_{Section} \quad \longrightarrow \quad 85.8 \text{ in}^3 < 166.0 \text{ in}^3 \quad \text{OK}$$

LPILE Plus for Windows, Version 5.0 (5.0.39)

Analysis of Individual Piles and Drilled Shafts
Subjected to Lateral Loading Using the p-y Method

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This program is licensed to:

Path to file locations: J:\GEOTECH\Projects\2010\B-10-020 HAM-75-7.85\HAM-75-7.85 PID 77889 -
Mainline\Analysis\Retaining Wall \B-027 - Pile and Lagging - 12.0 ft Wall Ht\Revised Analysis - 8-8-13\
Name of input data file: B-027 - Pile and Lagging - 12.0 ft Wall Ht - 8-8-13.lpd
Name of output file: B-027 - Pile and Lagging - 12.0 ft Wall Ht - 8-8-13.lpo
Name of plot output file: B-027 - Pile and Lagging - 12.0 ft Wall Ht - 8-8-13.lpp
Name of runtime file: B-027 - Pile and Lagging - 12.0 ft Wall Ht - 8-8-13.lpr

Time and Date of Analysis

Date: August 8, 2013 Time: 15:26:29

Problem Title

HAM-75-7.85 - Retaining Wall U - B-027-0-12 - 12.0 ft Wall Ht - Service

Program Options

Units Used in Computations - US Customary Units: Inches, Pounds

Basic Program Options:

Analysis Type 1:

- Computation of Lateral Pile Response Using User-specified Constant EI

Computation Options:

- Only internally-generated p-y curves used in analysis
- Analysis uses p-y multipliers for group action
- Analysis assumes no shear resistance at pile tip
- Analysis includes automatic computation of pile-top deflection vs. pile embedment length
- No computation of foundation stiffness matrix elements
- Output pile response for full length of pile
- Analysis assumes no soil movements acting on pile
- No additional p-y curves to be computed at user-specified depths

Solution Control Parameters:

- Number of pile increments = 100
- Maximum number of iterations allowed = 100
- Deflection tolerance for convergence = 1.0000E-05 in
- Maximum allowable deflection = 1.0000E+02 in

Printing Options:

- Values of pile-head deflection, bending moment, shear force, and soil reaction are printed for full length of pile.
- Printing Increment (spacing of output points) = 1

Pile Structural Properties and Geometry

Pile Length = 396.00 in

B-027 - Pile and Lagging - 12.0 ft Wall Ht - 8-8-13.lpo

Depth of ground surface below top of pile = 144.00 in

Slope angle of ground surface = .00 deg.

Structural properties of pile defined using 4 points

Point	Depth X in	Pile Diameter in	Moment of Inertia in**4	Pile Area Sq. in	Modulus of Elasticity lbs/Sq. in
1	0.0000	18.40000000	1530.0000	25.3000	29000000.
2	144.0000	18.40000000	1530.0000	25.3000	29000000.
3	144.0000	30.00000000	39761.0000	706.9000	3604997.
4	396.0000	30.00000000	39761.0000	706.9000	3604997.

Soil and Rock Layering Information

The soil profile is modelled using 3 layers

Layer 1 is stiff clay without free water
 Distance from top of pile to top of layer = 144.000 in
 Distance from top of pile to bottom of layer = 228.000 in

Layer 2 is stiff clay without free water
 Distance from top of pile to top of layer = 228.000 in
 Distance from top of pile to bottom of layer = 456.000 in

Layer 3 is stiff clay without free water
 Distance from top of pile to top of layer = 456.000 in
 Distance from top of pile to bottom of layer = 552.000 in

(Depth of lowest layer extends 156.00 in below pile tip)

Effective Unit Weight of Soil vs. Depth

Effective unit weight of soil with depth defined using 6 points

Point No.	Depth X in	Eff. Unit Weight lbs/in**3
1	144.00	.06900
2	228.00	.06900
3	228.00	.06900
4	456.00	.06900
5	456.00	.06700
6	552.00	.06700

Shear Strength of Soils

Shear strength parameters with depth defined using 6 points

Point No.	Depth X in	Cohesion c lbs/in**2	Angle of Friction Deg.	E50 or k _{rm}	RQD %
1	144.000	17.40000	.00	.00600	.0
2	228.000	17.40000	.00	.00600	.0
3	228.000	24.30000	.00	.00500	.0
4	456.000	24.30000	.00	.00500	.0
5	456.000	8.70000	.00	.00700	.0
6	552.000	8.70000	.00	.00700	.0

Notes:

- (1) Cohesion = uniaxial compressive strength for rock materials.
- (2) Values of E50 are reported for clay strata.
- (3) Default values will be generated for E50 when input values are 0.
- (4) RQD and k_{rm} are reported only for weak rock strata.

 p-y Modification Factors

Distribution of p-y multipliers with depth defined using 2 points

Point No.	Depth X in	p-mult	y-mult
1	144.000	.9477	1.0000
2	552.000	.9477	1.0000

 Loading Type

Static loading criteria was used for computation of p-y curves.

 Distributed Lateral Loading

Distributed lateral load intensity defined using 2 points

Point No.	Depth X in	Dist. Load lbs/in
1	.000	.00000
2	144.000	544.40000

 Pile-head Loading and Pile-head Fixity Conditions

Number of loads specified = 1

Load Case Number 1

Pile-head boundary conditions are Shear and Moment (BC Type 1)

Shear force at pile head = .000 lbs
 Bending moment at pile head = .000 in-lbs
 Axial load at pile head = .000 lbs

(Zero moment at pile head for this load indicates a free-head condition)

 Computed Values of Load Distribution and Deflection
 for Lateral Loading for Load Case Number 1

Pile-head boundary conditions are Shear and Moment (BC Type 1)

Specified shear force at pile head = .000 lbs
 Specified moment at pile head = .000 in-lbs
 Specified axial load at pile head = .000 lbs

(Zero moment for this load indicates free-head conditions)

Depth X in	Deflect. y in	Moment M lbs-in	Shear V lbs	Slope S Rad.	Total Stress lbs/in**2	Soil Res. p lbs/in	Es*h F/L lbs/in
0.000	.749982	7.2250E-06	0.0000	-.0042112	4.3444E-08	0.0000	0.0000
3.960	.733306	14.6731	33.3479	-.0042112	.0882302	0.0000	0.0000
7.920	.716630	264.1154	122.2756	-.0042111	1.5881	0.0000	0.0000
11.880	.699954	983.0962	270.4885	-.0042111	5.9114	0.0000	0.0000
15.840	.683278	2406.3846	477.9866	-.0042109	14.4698	0.0000	0.0000
19.800	.666603	4768.7501	744.7698	-.0042106	28.6748	0.0000	0.0000

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23.760	.649930	8304.9616	1070.8382	-.0042100	49.9383	0.0000	0.0000
27.720	.633260	13249.7886	1456.1917	-.0042091	79.6719	0.0000	0.0000
31.680	.616594	19838.0002	1900.8304	-.0042076	119.2873	0.0000	0.0000
35.640	.599936	28304.3657	2404.7543	-.0042054	170.1962	0.0000	0.0000
39.600	.583287	38883.6543	2967.9633	-.0042024	233.8102	0.0000	0.0000
43.560	.566652	51810.6352	3590.4575	-.0041984	311.5411	0.0000	0.0000
47.520	.550036	67320.0777	4272.2368	-.0041931	404.8005	0.0000	0.0000
51.480	.533443	85646.7510	5013.3013	-.0041863	515.0001	0.0000	0.0000
55.440	.516881	107025.	5813.6510	-.0041777	643.5516	0.0000	0.0000
59.400	.500356	131691.	6673.2858	-.0041670	791.8667	0.0000	0.0000
63.360	.483878	159878.	7592.2058	-.0041540	961.3570	0.0000	0.0000
67.320	.467456	191821.	8570.4109	-.0041383	1153.4343	0.0000	0.0000
71.280	.451103	227756.	9607.9012	-.0041196	1369.5102	0.0000	0.0000
75.240	.434829	267916.	10704.6767	-.0040975	1610.9965	0.0000	0.0000
79.200	.418651	312537.	11860.7373	-.0040716	1879.3047	0.0000	0.0000
83.160	.402583	361853.	13076.0831	-.0040415	2175.8466	0.0000	0.0000
87.120	.386642	416099.	14350.7140	-.0040067	2502.0339	0.0000	0.0000
91.080	.370849	475510.	15684.6301	-.0039670	2859.2783	0.0000	0.0000
95.040	.355224	540321.	17077.8314	-.0039216	3248.9914	0.0000	0.0000
99.000	.339790	610767.	18530.3178	-.0038703	3672.5849	0.0000	0.0000
102.960	.324572	687082.	20042.0894	-.0038123	4131.4705	0.0000	0.0000
106.920	.309596	769500.	21613.1461	-.0037473	4627.0599	0.0000	0.0000
110.880	.294893	858258.	23243.4880	-.0036747	5160.7648	0.0000	0.0000
114.840	.280493	953589.	24933.1151	-.0035939	5733.9969	0.0000	0.0000
118.800	.266429	1055728.	26682.0273	-.0035042	6348.1677	0.0000	0.0000
122.760	.252739	1164910.	28490.2247	-.0034051	7004.6892	0.0000	0.0000
126.720	.239461	1281370.	30357.7072	-.0032959	7704.9728	0.0000	0.0000
130.680	.226636	1405343.	32284.4749	-.0031760	8450.4303	0.0000	0.0000
134.640	.214307	1537064.	34270.5278	-.0030447	9242.4734	0.0000	0.0000
138.600	.202521	1676766.	36315.8658	-.0029013	10082.5138	0.0000	0.0000
142.560	.191329	1824685.	38273.2254	-.0027451	10971.9631	0.0000	0.0000
146.520	.180781	1979890.	38003.0779	-.0026363	746.9215	-601.0186	13165.3219
150.480	.170449	2125670.	35609.0306	-.0025796	801.9175	-608.0962	14127.7416
154.440	.160350	2261913.	33188.2972	-.0025190	853.3161	-614.4964	15175.5640
158.400	.150499	2388521.	30743.5944	-.0024547	901.0793	-620.2019	16319.0537
162.360	.140909	2505403.	28277.7086	-.0023871	945.1734	-625.1949	17570.0255
166.320	.131593	2612480.	25793.4979	-.0023164	985.5689	-629.4570	18942.1337
170.280	.122563	2709687.	23293.8942	-.0022429	1022.2406	-632.9691	20451.2262
174.240	.113829	2796968.	20781.9066	-.0021668	1055.1676	-635.7115	22115.7819
178.200	.105401	2874280.	18260.6247	-.0020885	1084.3338	-637.6632	23957.4531
182.160	.097288	2941592.	15733.2222	-.0020082	1109.7277	-638.8027	26001.7443
186.120	.089497	2998887.	13202.9619	-.0019261	1131.3424	-639.1066	28278.8669
190.080	.082033	3046160.	10673.2007	-.0018426	1149.1762	-638.5506	30824.8269
194.040	.074903	3083419.	8147.3960	-.0017579	1163.2323	-637.1083	33682.8196
198.000	.068110	3110687.	5629.1135	-.0016724	1173.5194	-634.7515	36905.0369
201.960	.061658	3128001.	3122.0355	-.0015862	1180.0513	-631.4494	40555.0362
205.920	.055548	3135413.	629.9723	-.0014997	1182.8476	-627.1684	44710.8807
209.880	.049780	3132991.	-1843.1257	-.0014131	1181.9335	-621.8710	49469.3606
213.840	.044356	3120816.	-4293.1514	-.0013267	1177.3406	-615.5157	53951.7486
217.800	.039273	3098989.	-6715.8218	-.0012408	1169.1062	-608.0552	61311.7799
221.760	.034529	3067627.	-9106.6534	-.0011556	1157.2747	-599.4355	68746.9209
225.720	.030121	3026864.	-11460.9310	-.0010714	1141.8969	-589.5936	77514.6178
229.680	.026043	2976856.	-14123.6964	-.0009885	1123.0311	-575.2374	114837.
233.640	.022292	2915005.	-17083.4991	-.0009071	1099.6974	-739.6124	131387.
237.600	.018859	2841555.	-19977.4340	-.0008276	1071.9881	-721.9708	151597.
241.560	.015737	2756783.	-22797.1322	-.0007502	1040.0078	-702.1192	176674.
245.520	.012917	2661001.	-25533.3308	-.0006754	1003.8737	-679.7993	208404.
249.480	.010388	2554559.	-28175.5450	-.0006034	963.7179	-654.6524	249554.
253.440	.008139	2437851.	-30711.5450	-.0005344	919.6893	-626.1557	304668.
257.400	.006156	2311324.	-33126.4616	-.0004688	871.9564	-593.4991	381798.
261.360	.004426	2175490.	-35401.1245	-.0004068	820.7123	-555.3205	496880.
265.320	.002934	2030947.	-37508.5555	-.0003487	766.1830	-509.0386	687104.
269.280	.001664	1878422.	-39404.8631	-.0002947	708.6423	-448.6925	1067839.
273.240	.000600	1718860.	-41030.1830	-.0002450	648.4471	-372.1761	2457847.
277.200	-.000277	1553463.	-41422.0070	-.0001998	586.0502	174.2852	2495013.
281.160	-.000983	1390798.	-40262.7443	-.0001591	524.6843	411.2009	1656645.
285.120	-.001537	1234582.	-38524.5898	-.0001229	465.7510	466.6549	1202256.
289.080	-.001956	1085683.	-36604.9708	-9.0831E-05	409.5785	502.8497	1017961.
293.040	-.002256	944670.	-34562.7459	-6.2785E-05	356.3808	528.5770	927634.
297.000	-.002453	811946.	-32432.4069	-3.8520E-05	306.3101	547.3518	883470.
300.960	-.002562	687806.	-30237.9410	-1.7803E-05	259.4775	560.9642	867222.
304.920	-.002594	572462.	-27997.7268	-3.9463E-07	215.9636	570.4571	870722.
308.880	-.002565	466064.	-25726.7667	1.3951E-05	175.8245	576.4925	890142.
312.840	-.002484	368706.	-23437.8686	2.5482E-05	139.0958	579.5166	923897.
316.800	-.002363	280436.	-21142.3375	3.4449E-05	105.7956	579.8425	971786.
320.760	-.002211	201259.	-18850.4117	4.1103E-05	75.9256	577.6958	1034640.
324.720	-.002037	131141.	-16571.5571	4.5694E-05	49.4733	573.2409	1114233.
328.680	-.001849	70011.8844	-14314.6797	4.8473E-05	26.4123	566.5962	1213358.
332.640	-.001653	17768.3199	-12088.2927	4.9686E-05	6.7032	557.8417	1336067.

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336.600	-	.001456	-25727.3941	-9900.6639	4.9576E-05	9.7058	547.0214	1488112.
340.560	-	.001261	-60644.9379	-7759.9672	4.8383E-05	22.8786	534.1386	1677709.
344.520	-	.001072	-87186.3344	-5674.4673	4.6341E-05	32.8914	519.1442	1916871.
348.480	-	.000894	-105587.	-3652.7769	4.3678E-05	39.8330	501.9115	2223870.
352.440	-	.000727	-116116.	-1704.2632	4.0615E-05	43.8054	482.1864	2628096.
356.400	-	.000572	-119084.	176.7409	3.7366E-05	44.9251	467.8157	3238320.
360.360	-	.000431	-114717.	1808.2529	3.4137E-05	43.2773	356.1802	3275486.
364.320	-	.000302	-104763.	3013.2186	3.1105E-05	39.5223	252.3883	3312651.
368.280	-	.000184	-90851.8487	3821.5740	2.8403E-05	34.2742	155.8720	3349817.
372.240	-7.68E-05	-74496.2540	4260.1926	2.6119E-05	28.1040	65.6525	3386982.	
376.200	2.26E-05	-57111.1230	4351.5000	2.4301E-05	21.5454	-19.5377	3424147.	
380.160	.000116	-40032.3742	4112.5749	2.2959E-05	15.1024	-101.1315	3461313.	
384.120	.000204	-24539.5298	3554.7389	2.2067E-05	9.2576	-180.6038	3498478.	
388.080	.000290	-11878.8423	2683.6411	2.1564E-05	4.4813	-259.3445	3535644.	
392.040	.000375	-3285.0922	1499.8538	2.1354E-05	1.2393	-338.5278	3572809.	
396.000	.000460	0.0000	0.0000	2.1309E-05	0.0000	-418.9741	1804987.	

Output Veri fication:

Computed forces and moments are withi n speci fied convergence l imi ts.

Output Summary for Load Case No. 1:

Pile-head deflection	=	.74998243 in
Computed slope at pile head	=	-.00421116
Maximum bending moment	=	3135413. lbs-in
Maximum shear force	=	-41422.00696 lbs
Depth of maximum bending moment	=	205.92000 in
Depth of maximum shear force	=	277.20000 in
Number of iterations	=	22
Number of zero deflection points	=	2

 Summary of Pile Response(s)

Defini tion of Symbols for Pile-Head Loading Condi ti ons:

Type 1 = Shear and Moment,	y = pile-head displacement in
Type 2 = Shear and Slope,	M = Pile-head Moment lbs-in
Type 3 = Shear and Rot. Stiffness,	V = Pile-head Shear Force lbs
Type 4 = Deflection and Moment,	S = Pile-head Slope, radians
Type 5 = Deflection and Slope,	R = Rot. Stiffness of Pile-head in-lbs/rad

Load Type	Pile-Head Condition 1	Pile-Head Condition 2	Axial Load lbs	Pile-Head Deflection in	Maximum Moment in-lbs	Maximum Shear lbs
1	V=	0.000 M=	0.000	.7499824	3135413.	-41422.0070

 Pile-head Deflecti on vs. Pile Length

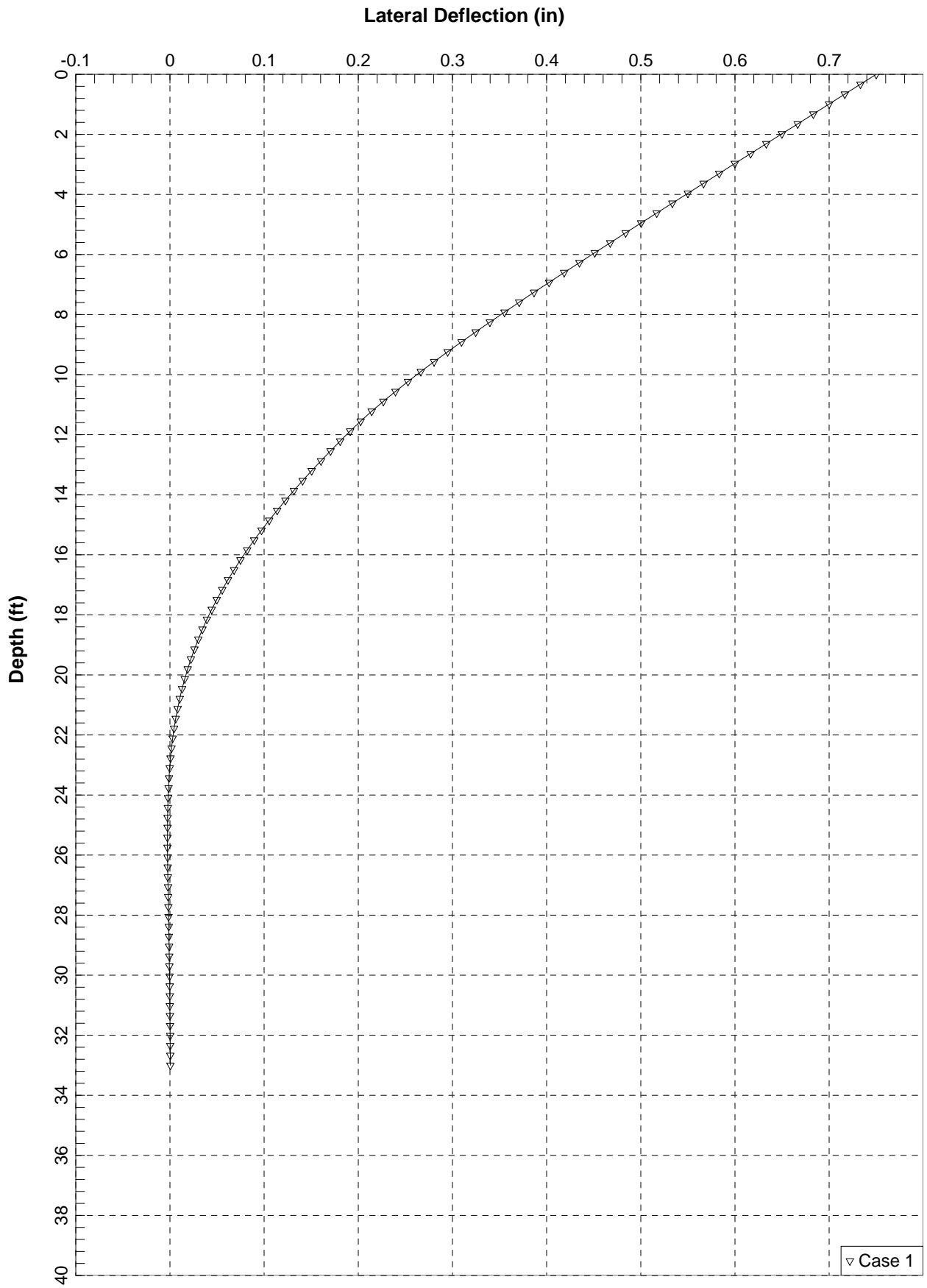
Boundary Condi ti on Type 1, Shear and Moment

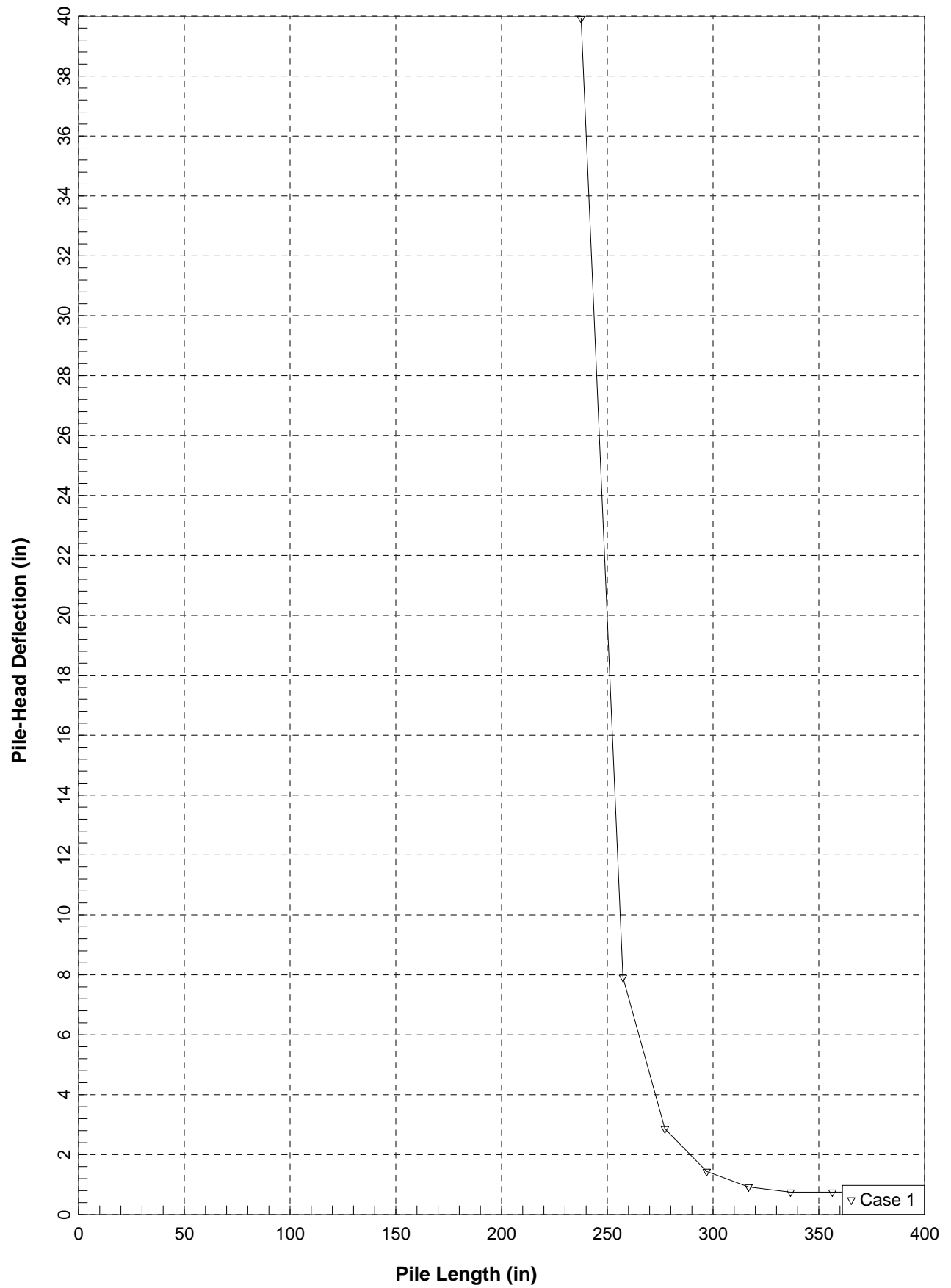
Shear	=	0. lbs
Moment	=	0. in-lbs
Axial Load	=	0. lbs

Pile Length in	Pile Head Deflection in	Maximum Moment in-lbs	Maximum Shear lbs
396.000	.74998243	3135413.	-41422.00696
376.200	.75442329	3144162.	-41176.20908
356.400	.74712077	3130274.	-40819.98915
336.600	.75033892	3071198.	-42759.68263
316.800	.91977315	3005828.	-47633.42384
297.000	1.44000333	2847719.	-50488.25910
277.200	2.86106973	2642647.	-51561.12025

257.400	7.91960569	B-027 - Pile and Lagging - 12.0 ft Wall Ht - 8-8-13.lpo
237.600	39.91727993	2477715. -53874.61857
		2362973. -59382.31644

The analysis ended normally.





LPILE Plus for Windows, Version 5.0 (5.0.39)

Analysis of Individual Piles and Drilled Shafts
Subjected to Lateral Loading Using the p-y Method

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This program is licensed to:

Path to file locations: J:\GEOTECH\Projects\2010\B-10-020 HAM-75-7.85\HAM-75-7.85 PID 77889 -
Mainline\Analysis\Retaining Wall U\B-027 - Pile and Lagging - 12.0 ft Wall Ht\Revised Analysis - 8-8-13\
Name of input data file: B-027 - Pile and Lagging - 12.0 ft Wall Ht - 8-8-13.lpd
Name of output file: B-027 - Pile and Lagging - 12.0 ft Wall Ht - 8-8-13.lpo
Name of plot output file: B-027 - Pile and Lagging - 12.0 ft Wall Ht - 8-8-13.lpp
Name of runtime file: B-027 - Pile and Lagging - 12.0 ft Wall Ht - 8-8-13.lpr

Time and Date of Analysis

Date: August 8, 2013 Time: 15:35:12

Problem Title

HAM-75-7.85 - Retaining Wall U - B-027-0-12 - 12.0 ft Wall Ht - Strength

Program Options

Units Used in Computations - US Customary Units: Inches, Pounds

Basic Program Options:

Analysis Type 1:

- Computation of Lateral Pile Response Using User-specified Constant EI

Computation Options:

- Only internally-generated p-y curves used in analysis
- Analysis uses p-y multipliers for group action
- Analysis assumes no shear resistance at pile tip
- Analysis includes automatic computation of pile-top deflection vs. pile embedment length
- No computation of foundation stiffness matrix elements
- Output pile response for full length of pile
- Analysis assumes no soil movements acting on pile
- No additional p-y curves to be computed at user-specified depths

Solution Control Parameters:

- Number of pile increments = 100
- Maximum number of iterations allowed = 100
- Deflection tolerance for convergence = 1.0000E-05 in
- Maximum allowable deflection = 1.0000E+02 in

Printing Options:

- Values of pile-head deflection, bending moment, shear force, and soil reaction are printed for full length of pile.
- Printing Increment (spacing of output points) = 1

Pile Structural Properties and Geometry

Pile Length = 396.00 in

B-027 - Pile and Lagging - 12.0 ft Wall Ht - 8-8-13.lpo

Depth of ground surface below top of pile = 144.00 in

Slope angle of ground surface = .00 deg.

Structural properties of pile defined using 4 points

Point	Depth X in	Pile Diameter in	Moment of Inertia in**4	Pile Area Sq. in	Modulus of Elasticity lbs/Sq. in
1	0.0000	18.40000000	1530.0000	25.3000	29000000.
2	144.0000	18.40000000	1530.0000	25.3000	29000000.
3	144.0000	30.00000000	39761.0000	706.9000	3604997.
4	396.0000	30.00000000	39761.0000	706.9000	3604997.

Soil and Rock Layering Information

The soil profile is modelled using 3 layers

Layer 1 is stiff clay without free water
 Distance from top of pile to top of layer = 144.000 in
 Distance from top of pile to bottom of layer = 228.000 in

Layer 2 is stiff clay without free water
 Distance from top of pile to top of layer = 228.000 in
 Distance from top of pile to bottom of layer = 456.000 in

Layer 3 is stiff clay without free water
 Distance from top of pile to top of layer = 456.000 in
 Distance from top of pile to bottom of layer = 552.000 in

(Depth of lowest layer extends 156.00 in below pile tip)

Effective Unit Weight of Soil vs. Depth

Effective unit weight of soil with depth defined using 6 points

Point No.	Depth X in	Eff. Unit Weight lbs/in**3
1	144.00	.06900
2	228.00	.06900
3	228.00	.06900
4	456.00	.06900
5	456.00	.06700
6	552.00	.06700

Shear Strength of Soils

Shear strength parameters with depth defined using 6 points

Point No.	Depth X in	Cohesion c lbs/in**2	Angle of Friction Deg.	E50 or k _{rm}	RQD %
1	144.000	17.40000	.00	.00600	.0
2	228.000	17.40000	.00	.00600	.0
3	228.000	24.30000	.00	.00500	.0
4	456.000	24.30000	.00	.00500	.0
5	456.000	8.70000	.00	.00700	.0
6	552.000	8.70000	.00	.00700	.0

Notes:

- (1) Cohesion = uniaxial compressive strength for rock materials.
- (2) Values of E50 are reported for clay strata.
- (3) Default values will be generated for E50 when input values are 0.
- (4) RQD and k_{rm} are reported only for weak rock strata.

 p-y Modification Factors

Distribution of p-y multipliers with depth defined using 2 points

Point No.	Depth X in	p-mult	y-mult
1	144.000	.9477	1.0000
2	552.000	.9477	1.0000

 Loading Type

Static loading criteria was used for computation of p-y curves.

 Distributed Lateral Loading

Distributed lateral load intensity defined using 2 points

Point No.	Depth X in	Dist. Load lbs/in
1	.000	.00000
2	144.000	816.60000

 Pile-head Loading and Pile-head Fixity Conditions

Number of loads specified = 1

Load Case Number 1

Pile-head boundary conditions are Shear and Moment (BC Type 1)

Shear force at pile head = .000 lbs
 Bending moment at pile head = .000 in-lbs
 Axial load at pile head = .000 lbs

(Zero moment at pile head for this load indicates a free-head condition)

 Computed Values of Load Distribution and Deflection
 for Lateral Loading for Load Case Number 1

Pile-head boundary conditions are Shear and Moment (BC Type 1)

Specified shear force at pile head = .000 lbs
 Specified moment at pile head = .000 in-lbs
 Specified axial load at pile head = .000 lbs

(Zero moment for this load indicates free-head conditions)

Depth X in	Deflect. y in	Moment M lbs-in	Shear V lbs	Slope S Rad.	Total Stress lbs/in**2	Soil Res. p lbs/in	Es*h F/L lbs/in
0.000	1.376	-1.2565E-06	0.0000	-.0072403	7.5555E-09	0.0000	0.0000
3.960	1.348	22.0096	50.0219	-.0072403	.1323455	0.0000	0.0000
7.920	1.319	396.1731	183.4135	-.0072403	2.3822	0.0000	0.0000
11.880	1.290	1474.6443	405.7328	-.0072402	8.8671	0.0000	0.0000
15.840	1.262	3609.5770	716.9799	-.0072400	21.7046	0.0000	0.0000
19.800	1.233	7153.1251	1117.1547	-.0072395	43.0123	0.0000	0.0000

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23.760	1.204	12457.4425	1606.2573	-0072386	74.9075	0.0000	0.0000
27.720	1.176	19874.6829	2184.2876	-0072372	119.5079	0.0000	0.0000
31.680	1.147	29757.0004	2851.2457	-0072350	178.9310	0.0000	0.0000
35.640	1.118	42456.5486	3607.1315	-0072318	255.2943	0.0000	0.0000
39.600	1.090	58325.4815	4451.9450	-0072273	350.7153	0.0000	0.0000
43.560	1.061	77715.9529	5385.6863	-0072212	467.3116	0.0000	0.0000
47.520	1.033	100980.	6408.3553	-0072132	607.2007	0.0000	0.0000
51.480	1.004	128470.	7519.9520	-0072030	772.5001	0.0000	0.0000
55.440	.975463	160538.	8720.4765	-0071901	965.3274	0.0000	0.0000
59.400	.947018	197536.	10009.9287	-0071741	1187.8000	0.0000	0.0000
63.360	.918644	239817.	11388.3087	-0071546	1442.0355	0.0000	0.0000
67.320	.890354	287732.	12855.6164	-0071310	1730.1514	0.0000	0.0000
71.280	.862166	341633.	14411.8519	-0071030	2054.2653	0.0000	0.0000
75.240	.834098	401874.	16057.0151	-0070698	2416.4947	0.0000	0.0000
79.200	.806173	468805.	17791.1060	-0070309	2818.9570	0.0000	0.0000
83.160	.778414	542779.	19614.1247	-0069858	3263.7699	0.0000	0.0000
87.120	.750846	624149.	21526.0711	-0069337	3753.0509	0.0000	0.0000
91.080	.723499	713266.	23526.9452	-0068740	4288.9174	0.0000	0.0000
95.040	.696403	810482.	25616.7471	-0068060	4873.4871	0.0000	0.0000
99.000	.669595	916150.	27795.4767	-0067290	5508.8773	0.0000	0.0000
102.960	.643110	1030622.	30063.1341	-0066421	6197.2058	0.0000	0.0000
106.920	.616989	1154250.	32419.7192	-0065446	6940.5899	0.0000	0.0000
110.880	.591277	1287386.	34865.2321	-0064357	7741.1472	0.0000	0.0000
114.840	.566019	1430383.	37399.6727	-0063144	8600.9953	0.0000	0.0000
118.800	.541267	1583592.	40023.0410	-0061799	9522.2516	0.0000	0.0000
122.760	.517074	1747365.	42735.3371	-0060312	10507.0338	0.0000	0.0000
126.720	.493499	1922056.	45536.5609	-0058675	11557.4592	0.0000	0.0000
130.680	.470604	2108015.	48426.7124	-0056876	12675.6455	0.0000	0.0000
134.640	.448453	2305595.	51405.7917	-0054907	13863.7102	0.0000	0.0000
138.600	.427118	2515149.	54473.7987	-0052756	15123.7707	0.0000	0.0000
142.560	.406671	2737028.	57409.8381	-0050412	16457.9447	0.0000	0.0000
146.520	.387191	2969835.	57350.0439	-0048780	1120.3823	-727.0698	7436.1061
150.480	.368037	3191240.	54450.9389	-0047929	1203.9084	-737.1247	7931.3079
154.440	.349231	3401086.	51513.3797	-0047019	1283.0737	-746.4911	8464.5995
158.400	.330798	3599226.	48540.1252	-0046052	1357.8228	-755.1526	9039.9654
162.360	.312759	3785524.	45534.0001	-0045031	1428.1044	-763.0925	9661.9102
166.320	.295133	3959855.	42497.8958	-0043962	1493.8716	-770.2935	10335.5418
170.280	.277941	4122107.	39434.7731	-0042845	1555.0819	-776.7381	11066.6714
174.240	.261200	4272179.	36347.6636	-0041686	1611.6969	-782.4081	11861.9326
178.200	.244926	4409981.	33239.6726	-0040486	1663.6833	-787.2844	12728.9251
182.160	.229135	4535437.	30113.9813	-0039251	1711.0122	-791.3476	13676.3891
186.120	.213840	4648484.	26973.8504	-0037982	1753.6594	-794.5771	14714.4173
190.080	.199053	4749070.	23822.6232	-0036684	1791.6060	-796.9517	15854.7140
194.040	.184786	4837159.	20663.7301	-0035360	1824.8379	-798.4489	17110.9156
198.000	.171048	4912727.	17500.6924	-0034013	1853.3462	-799.0449	18498.9874
201.960	.157848	4975764.	14337.1287	-0032647	1877.1274	-798.7146	20037.7201
205.920	.145192	5026277.	11176.7600	-0031265	1896.1834	-797.4312	21749.3559
209.880	.133086	5064284.	8023.4174	-0029871	1910.5219	-795.1661	23660.3826
213.840	.121534	5089822.	4881.0502	-0028469	1920.1562	-791.8881	25802.5545
217.800	.110538	5102942.	1753.7355	-0027061	1925.1058	-787.5638	28214.2124
221.760	.100101	5103712.	-1354.3102	-0025651	1925.3961	-782.1563	30942.0147
225.720	.090223	5092216.	-4438.7173	-0024243	1921.0593	-775.6251	34043.2296
229.680	.080901	5068557.	-7959.6262	-0022839	1912.1339	-1002.6118	49076.3747
233.640	.072134	5029176.	-11908.8440	-0021444	1897.2771	-991.9427	54455.2580
237.600	.063918	4974239.	-15812.3945	-0020062	1876.5520	-979.5475	60687.6899
241.560	.056245	4903942.	-19663.2608	-0018698	1850.0320	-965.3344	67965.6297
245.520	.049109	4818506.	-23454.0268	-0017355	1817.8011	-949.1938	76540.2701
249.480	.042500	4718186.	-27176.7948	-0016037	1779.9548	-930.9920	86746.6096
253.440	.036407	4603266.	-30823.0725	-0014750	1736.6009	-910.5624	99041.4939
257.400	.030818	4474067.	-34383.6160	-0013496	1687.8600	-887.6919	114065.
261.360	.025718	4330948.	-37848.2047	-0012280	1633.8677	-862.1004	132742.
265.320	.021093	4174309.	-41205.3071	-0011105	1574.7752	-833.4059	156466.
269.280	.016923	4004602.	-44441.5628	-0009975	1510.7523	-801.0667	187445.
273.240	.013192	3822332.	-47540.9362	-0008894	1441.9904	-764.2733	229413.
277.200	.009880	3628077.	-50483.2259	-0007865	1368.7070	-721.7316	289290.
281.160	.006964	3422505.	-53241.1669	-0006891	1291.1539	-671.1679	381672.
285.120	.004422	3206407.	-55773.8428	-0005975	1209.6303	-607.9614	544428.
289.080	.002231	2980776.	-58006.9568	-0005120	1124.5099	-519.8740	922606.
293.040	.000367	2746992.	-59521.1310	-0004329	1036.3140	-244.8605	2643674.
297.000	-.001197	2509369.	-59100.4183	-0003603	946.6696	457.3416	1512621.
300.960	-.002487	2278917.	-57092.4774	-0002942	859.7307	556.7700	886582.
304.920	-.003527	2057196.	-54770.5022	-0002343	776.0857	615.9448	691543.
308.880	-.004342	1845134.	-52248.9247	-0001804	696.0845	657.5792	599689.
312.840	-.004956	1643385.	-49583.2553	-0001322	619.9736	688.7185	550354.
316.800	-.005389	1452435.	-46808.7317	-8.9412E-05	547.9371	712.5560	523597.
320.760	-.005664	1272660.	-43950.8392	-5.1769E-05	480.1160	730.8240	510982.
324.720	-.005799	1104344.	-41029.5675	-1.8934E-05	416.6185	744.5657	508436.
328.680	-.005814	947705.	-38061.5147	9.4120E-06	357.5257	754.4508	513896.
332.640	-.005725	802897.	-35061.0726	3.3594E-05	302.8963	760.9240	526373.

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336.600	-	005548	670022.	-32041.1658	5.3940E-05	252.7684	764.2815	545559.
340.560	-	005297	549131.	-29013.7576	7.0781E-05	207.1620	764.7126	571654.
344.520	-	004987	440233.	-25990.2328	8.4447E-05	166.0796	762.3202	605327.
348.480	-	004629	343289.	-22981.7233	9.5271E-05	129.5070	757.1291	647770.
352.440	-	004232	258217.	-19999.4232	.0001036	97.4136	749.0831	700856.
356.400	-	003808	184893.	-17054.9391	.0001097	69.7517	738.0302	767451.
360.360	-	003364	123142.	-14160.7292	.0001140	46.4559	723.6920	851993.
364.320	-	002906	72740.1678	-11330.7191	.0001167	27.4415	705.6060	961638.
368.280	-	002440	33403.0359	-8581.2472	.0001181	12.6014	683.0162	1108634.
372.240	-	001970	4776.6902	-5932.6638	.0001187	1.8020	654.6522	1315886.
376.200	-	001500	-13583.6615	-3412.3600	.0001185	5.1245	618.2285	1632164.
380.160	-	001031	-22249.2012	-1061.5077	.0001180	8.3936	569.0707	2185095.
384.120	-	000565	-21990.8023	1053.7480	.0001174	8.2961	499.2403	3498478.
388.080	-	000101	-13903.5171	2221.3105	.0001169	5.2452	90.4377	3535644.
392.040	.	000361	-4398.0234	1755.4946	.0001167	1.6592	-325.6983	3572809.
396.000	.	000823	0.0000	0.0000	.0001166	0.0000	-560.9151	1349795.

Output Veri fication:

Computed forces and moments are withi n speci fied convergence limits.

Output Summary for Load Case No. 1:

Pile-head deflection	=	1.37631908	in
Computed slope at pile head	=	-.00724033	
Maximum bending moment	=	5103712.	lbs-in
Maximum shear force	=	-59521.13101	lbs
Depth of maximum bending moment	=	221.76000	in
Depth of maximum shear force	=	293.04000	in
Number of iterations	=	26	
Number of zero deflection points	=	2	

Summary of Pile Response(s)

Defini tion of Symbols for Pile-Head Loading Condi ti ons:

Type 1 = Shear and Moment,	y = pile-head displacement in
Type 2 = Shear and Slope,	M = Pile-head Moment lbs-in
Type 3 = Shear and Rot. Stiffness,	V = Pile-head Shear Force lbs
Type 4 = Deflection and Moment,	S = Pile-head Slope, radians
Type 5 = Deflection and Slope,	R = Rot. Stiffness of Pile-head in-lbs/rad

Load Type	Pile-Head Condition 1	Pile-Head Condition 2	Axial Load lbs	Pile-Head Deflection in	Maximum Moment in-lbs	Maximum Shear lbs		
1	V=	0.000	M=	0.000	0.0000	1.3763	5103712.	-59521.1310

Pile-head Deflection vs. Pile Length

Boundary Condi tion Type 1, Shear and Moment

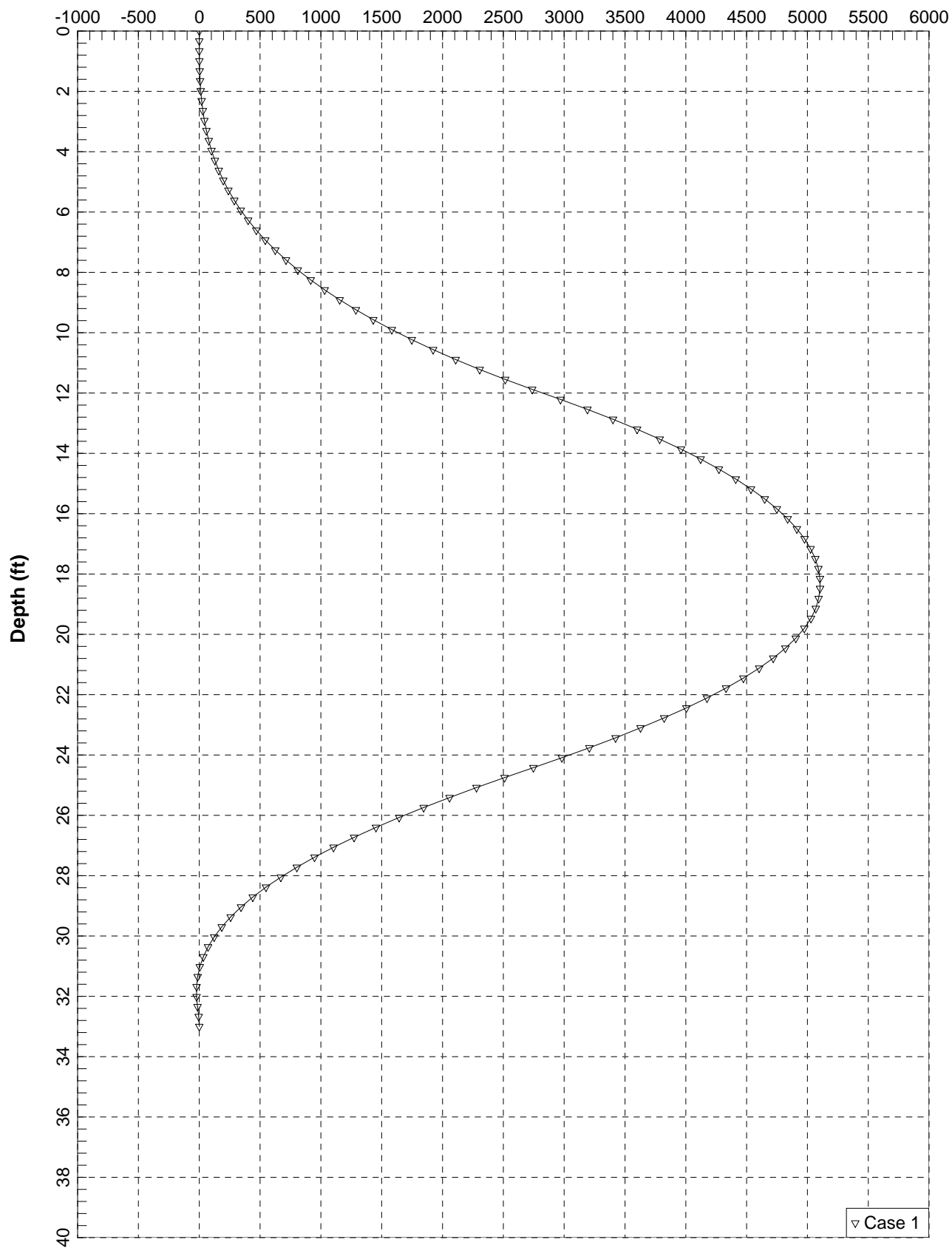
Shear	=	0.	lbs
Moment	=	0.	in-lbs
Axial Load	=	0.	lbs

Pile Length in	Pile Head Deflection in	Maximum Moment in-lbs	Maximum Shear lbs
396.000	1.37631908	5103712.	-59521.13101
376.200	1.38722463	5112191.	-60247.67560
356.400	1.46552973	5022062.	-65139.58066
336.600	1.77157215	4788424.	-69543.24623
316.800	2.86469964	4574417.	-73852.11680
297.000	5.73520060	4291075.	-76562.54988
277.200	13.16140290	3968818.	-77594.68047

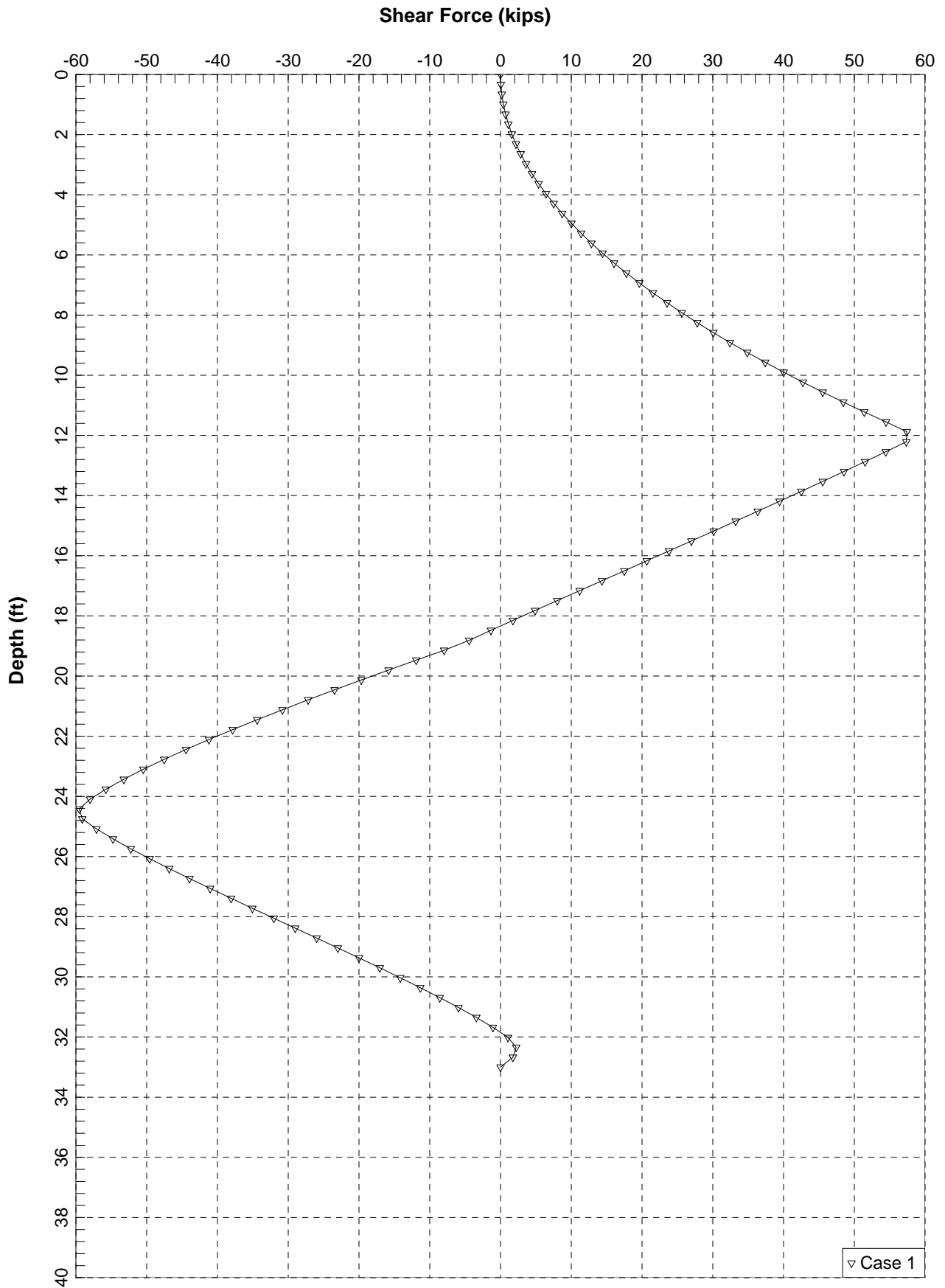
B-027 - Pile and Lagging - 12.0 ft Wall Ht - 8-8-13.lpo

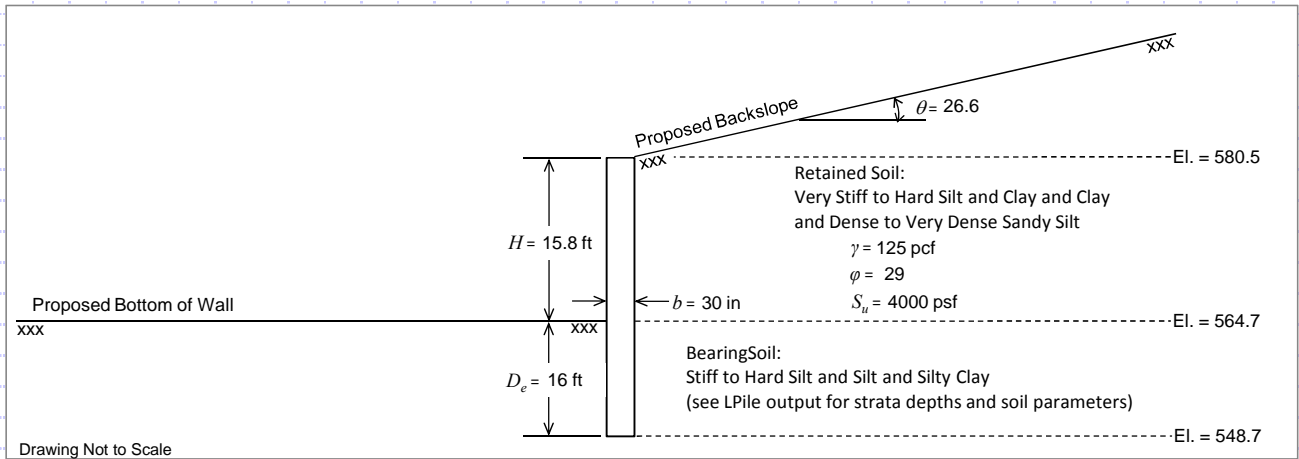
The analysis ended normally.

Bending Moment (in-kips)



▽ Case 1





Retaining Wall and Soil Parameters

Retaining Wall Height, (H) =	15.8 ft
Soil Friction Angle, (ϕ') =	29°
Soil Total Unit Weight, (γ) =	125 pcf
Soil Undrained Shear Strength, (s_u) =	4000 psf
Backslope Angle, (θ) =	26.6°
Embedment Depth, (D_e) =	16 ft
Shaft Spacing, (S) =	6.0 ft O.C.
Shaft Diameter, (b) =	30 in

Rankine Earth Pressures

$$K_a = \cos \beta \frac{\cos \beta - \sqrt{\cos^2 \beta - \cos^2 \phi}}{\cos \beta + \sqrt{\cos^2 \beta - \cos^2 \phi}}$$

$$K_a = 0.5848$$

$$K_p = \cos \beta \frac{\cos \beta + \sqrt{\cos^2 \beta - \cos^2 \phi}}{\cos \beta - \sqrt{\cos^2 \beta - \cos^2 \phi}}$$

$$K_p = 1.3679$$

LRFD Load Factors

	EH	LS
Strength I	1.50	1.75
Service I	1.00	1.00

(AASHTO LRFD BDM Tab. 3.4.1-1, 3.4.1-2 - Active Earth Pressure)

p-y Reduction Factor

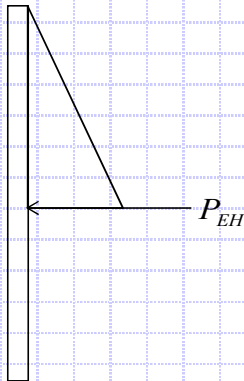
$S/b = 2.40$
 $\beta_a = 0.8685$

Structural Element Properties

Section Type: **W 18x86**

E = 29,000 ksi	d = 18.4 in	$I_x = 1530 \text{ in}^4$	$Z_x = 186 \text{ in}^3$
$A_s = 25.3 \text{ in}^2$	$t_w = 0.425 \text{ in}$	$I_x = 255.0 \text{ in}^4 \text{ per ft}$	$Z_x = 31.0 \text{ in}^3 \text{ per ft}$
$f_y = 50 \text{ ksi}$	$t_f = 0.680 \text{ in}$	$r_s = 7.77 \text{ in}$	T = 15.1 in
			S = 166.0 in ³

Lateral Loading of Cantilever Portion of Wall Retaining Soil - (Loading Case - Service I and Strength I)



Note: Required embedment and determination of structural capacity and allowable deflection at the top of the wall determined using LPile software. Loading conditions and material parameters used in the analysis are provided on this data page.

$$P_{EH} = \gamma H S K_a \gamma_{EH}$$

$$P_{EH} = (125 \text{ pcf})(15.8 \text{ ft})(6 \text{ ft O.C.})(0.585)(1.00) \quad (\text{Service I})$$

$$= (125 \text{ pcf})(15.8 \text{ ft})(6 \text{ ft O.C.})(0.585)(1.50) \quad (\text{Strength I})$$

$$P_{EH} = 6930.3 \text{ lb/ft} \quad (\text{Service I})$$

$$= 10395.5 \text{ lb/ft} \quad (\text{Strength I})$$

Check Deflection - (Loading Case - Service I)

$$\left(\frac{\delta_h}{H}\right) \cdot 100\% < 1.0\% \quad \longrightarrow \quad \delta_h = 1.754 \text{ in} \quad (\text{Determined from LPile}) \quad \longrightarrow \quad 0.93\% < 1.0\% \quad \text{OK}$$

Capacity Verification - (Loading Case - Strength I)

$\phi_f = 1.00$ $\phi_v = 1.00$ $C = 1.00$

Maximum Bending Moment, $M_u = 603.9$ kip-ft per section (Determined from LPile analysis)

Maximum Shear Force, $V_u = 92.1$ kip per section (Determined from LPile analysis)

Factored Flexural Resistance, $\phi_f M_n = 775.0$ kip-ft per section $\longrightarrow M_u < \phi_f M_n \longrightarrow 603.9 \text{ kip-ft} < 775.0 \text{ kip-ft}$ **OK**

Factored Shear Resistance, $\phi_v V_n = 226.5$ kip per section $\longrightarrow V_u < \phi_v V_n \longrightarrow 92.1 \text{ kip} < 226.5 \text{ kip}$ **OK**

$$S_{Req} = M_u \times \left(\frac{12}{50 \text{ ksi}}\right) = (603.9 \text{ kip-ft})(12 \text{ in}) / (50 \text{ ksi}) = 144.9 \text{ in}^3 \quad \longrightarrow \quad S_{Req} < S_{Section} \quad \longrightarrow \quad 144.9 \text{ in}^3 < 166.0 \text{ in}^3 \quad \text{OK}$$

B-029 - Pile and Lagging - 15.8 ft Wall Ht.lpo

LPILE Plus for Windows, Version 5.0 (5.0.39)

Analysis of Individual Piles and Drilled Shafts
Subjected to Lateral Loading Using the p-y Method

(c) 1985-2007 by Ensoft, Inc.
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This program is licensed to:

Path to file locations: J:\GEOTECH\Projects\2010\B-10-020 HAM-75-7.85\HAM-75-7.85 PID 77889 -
Mainline\Analysis\Retaining Wall U\B-029 - Pile and Lagging - 15.8 ft Wall Ht\
Name of input data file: B-029 - Pile and Lagging - 15.8 ft Wall Ht.lpd
Name of output file: B-029 - Pile and Lagging - 15.8 ft Wall Ht.lpo
Name of plot output file: B-029 - Pile and Lagging - 15.8 ft Wall Ht.lpp
Name of runtime file: B-029 - Pile and Lagging - 15.8 ft Wall Ht.lpr

Time and Date of Analysis

Date: August 8, 2013 Time: 14:34:47

Problem Title

HAM-75-7.85 - Retaining Wall U - B-029-0-11 - 15.8 ft Wall Height - Service

Program Options

Units Used in Computations - US Customary Units: Inches, Pounds

Basic Program Options:

Analysis Type 1:

- Computation of Lateral Pile Response Using User-specified Constant EI

Computation Options:

- Only internally-generated p-y curves used in analysis
- Analysis uses p-y multipliers for group action
- Analysis assumes no shear resistance at pile tip
- Analysis includes automatic computation of pile-top deflection vs. pile embedment length
- No computation of foundation stiffness matrix elements
- Output pile response for full length of pile
- Analysis assumes no soil movements acting on pile
- No additional p-y curves to be computed at user-specified depths

Solution Control Parameters:

- Number of pile increments = 100
- Maximum number of iterations allowed = 100
- Deflection tolerance for convergence = 1.0000E-05 in
- Maximum allowable deflection = 1.0000E+02 in

Printing Options:

- Values of pile-head deflection, bending moment, shear force, and soil reaction are printed for full length of pile.
- Printing Increment (spacing of output points) = 1

Pile Structural Properties and Geometry

Pile Length = 478.00 in

B-029 - Pile and Lagging - 15.8 ft Wall Ht. Ipo

Depth of ground surface below top of pile = 190.00 in

Slope angle of ground surface = .00 deg.

Structural properties of pile defined using 4 points

Point	Depth X in	Pile Diameter in	Moment of Inertia in**4	Pile Area Sq. in	Modulus of Elasticity lbs/Sq. in
1	0.0000	18.40000000	1530.0000	25.3000	29000000.
2	190.0000	18.40000000	1530.0000	25.3000	29000000.
3	190.0000	30.00000000	39761.0000	706.9000	3604997.
4	478.0000	30.00000000	39761.0000	706.9000	3604997.

Soil and Rock Layering Information

The soil profile is modelled using 3 layers

Layer 1 is stiff clay without free water
 Distance from top of pile to top of layer = 190.000 in
 Distance from top of pile to bottom of layer = 232.000 in

Layer 2 is stiff clay without free water
 Distance from top of pile to top of layer = 232.000 in
 Distance from top of pile to bottom of layer = 448.000 in

Layer 3 is stiff clay without free water
 Distance from top of pile to top of layer = 448.000 in
 Distance from top of pile to bottom of layer = 650.000 in

(Depth of lowest layer extends 172.00 in below pile tip)

Effective Unit Weight of Soil vs. Depth

Effective unit weight of soil with depth defined using 6 points

Point No.	Depth X in	Eff. Unit Weight lbs/in**3
1	190.00	.07200
2	232.00	.07200
3	232.00	.06900
4	448.00	.06900
5	448.00	.06700
6	650.00	.06700

Shear Strength of Soils

Shear strength parameters with depth defined using 6 points

Point No.	Depth X in	Cohesion c lbs/in**2	Angle of Friction Deg.	E50 or k _{rm}	RQD %
1	190.000	27.80000	.00	.00400	.0
2	232.000	27.80000	.00	.00400	.0
3	232.000	20.80000	.00	.00500	.0
4	448.000	20.80000	.00	.00500	.0
5	448.000	8.60000	.00	.00700	.0
6	650.000	8.60000	.00	.00700	.0

Notes:

- (1) Cohesion = uniaxial compressive strength for rock materials.
- (2) Values of E50 are reported for clay strata.
- (3) Default values will be generated for E50 when input values are 0.
- (4) RQD and k_{rm} are reported only for weak rock strata.

 p-y Modification Factors

Distribution of p-y multipliers with depth defined using 2 points

Point No.	Depth X in	p-mult	y-mult
1	190.000	.8685	1.0000
2	650.000	.8685	1.0000

 Loading Type

Static loading criteria was used for computation of p-y curves.

 Distributed Lateral Loading

Distributed lateral load intensity defined using 2 points

Point No.	Depth X in	Dist. Load lbs/in
1	.000	.00000
2	190.000	577.50000

 Pile-head Loading and Pile-head Fixity Conditions

Number of loads specified = 1

Load Case Number 1

Pile-head boundary conditions are Shear and Moment (BC Type 1)

Shear force at pile head = .000 lbs
 Bending moment at pile head = .000 in-lbs
 Axial load at pile head = .000 lbs

(Zero moment at pile head for this load indicates a free-head condition)

 Computed Values of Load Distribution and Deflection
 for Lateral Loading for Load Case Number 1

Pile-head boundary conditions are Shear and Moment (BC Type 1)

Specified shear force at pile head = .000 lbs
 Specified moment at pile head = .000 in-lbs
 Specified axial load at pile head = .000 lbs

(Zero moment for this load indicates free-head conditions)

Depth X in	Deflect. y in	Moment M lbs-in	Shear V lbs	Slope S Rad.	Total Stress lbs/in**2	Soil Res. p lbs/in	Es*h F/L lbs/in
0.000	1.609	5.1743E-06	-4.5104E-08	-.0077535	3.1114E-08	0.0000	0.0000
4.780	1.572	20.7473	39.0640	-.0077535	.1247552	0.0000	0.0000
9.560	1.535	373.4518	143.2347	-.0077535	2.2456	0.0000	0.0000
14.340	1.498	1390.0707	316.8524	-.0077534	8.3586	0.0000	0.0000
19.120	1.461	3402.5612	559.9173	-.0077532	20.4598	0.0000	0.0000
23.900	1.424	6742.8804	872.4293	-.0077526	40.5454	0.0000	0.0000

B-029 - Pile and Lagging - 15.8 ft Wall Ht. I po

28.680	1.387	11742.9855	1254.3884	-	0077516	70.6114	0.0000	0.0000
33.460	1.350	18734.8338	1705.7947	-	0077500	112.6539	0.0000	0.0000
38.240	1.313	28050.3824	2226.6480	-	0077475	168.6690	0.0000	0.0000
43.020	1.276	40021.5885	2816.9484	-	0077438	240.6527	0.0000	0.0000
47.800	1.239	54980.4093	3476.6960	-	0077387	330.6012	0.0000	0.0000
52.580	1.202	73258.8020	4205.8906	-	0077318	440.5104	0.0000	0.0000
57.360	1.165	95188.7238	5004.5324	-	0077227	572.3766	0.0000	0.0000
62.140	1.128	121102.	5872.6213	-	0077110	728.1958	0.0000	0.0000
66.920	1.091	151331.	6810.1573	-	0076964	909.9641	0.0000	0.0000
71.700	1.055	186207.	7817.1404	-	0076782	1119.6775	0.0000	0.0000
76.480	1.018	226063.	8893.5706	-	0076560	1359.3321	0.0000	0.0000
81.260	.981346	271230.	10039.4479	-	0076292	1630.9241	0.0000	0.0000
86.040	.944949	322040.	11254.7723	-	0075972	1936.4495	0.0000	0.0000
90.820	.908717	378825.	12539.5439	-	0075595	2277.9043	0.0000	0.0000
95.600	.872680	441918.	13893.7625	-	0075153	2657.2847	0.0000	0.0000
100.380	.836871	511650.	15317.4283	-	0074639	3076.5868	0.0000	0.0000
105.160	.801325	588353.	16810.5412	-	0074047	3537.8066	0.0000	0.0000
109.940	.766082	672359.	18373.1012	-	0073368	4042.9402	0.0000	0.0000
114.720	.731186	763999.	20005.1083	-	0072594	4593.9837	0.0000	0.0000
119.500	.696683	863607.	21706.5625	-	0071717	5192.9332	0.0000	0.0000
124.280	.662624	971514.	23477.4638	-	0070729	5841.7848	0.0000	0.0000
129.060	.629066	1088052.	25317.8122	-	0069619	6542.5345	0.0000	0.0000
133.840	.596068	1213552.	27227.6078	-	0068379	7297.1784	0.0000	0.0000
138.620	.563695	1348348.	29206.8504	-	0066999	8107.7126	0.0000	0.0000
143.400	.532017	1492770.	31255.5402	-	0065469	8976.1332	0.0000	0.0000
148.180	.501107	1647151.	33373.6771	-	0063778	9904.4363	0.0000	0.0000
152.960	.471045	1811822.	35561.2610	-	0061915	10894.6180	0.0000	0.0000
157.740	.441916	1987116.	37818.2921	-	0059868	11948.6742	0.0000	0.0000
162.520	.413811	2173365.	40144.7703	-	0057627	13068.6012	0.0000	0.0000
167.300	.386825	2370900.	42540.6956	-	0055179	14256.3950	0.0000	0.0000
172.080	.361059	2580054.	45006.0681	-	0052513	15514.0517	0.0000	0.0000
176.860	.336623	2801158.	47540.8876	-	0049614	16843.5674	0.0000	0.0000
181.640	.313628	3034545.	50145.1542	-	0046471	18246.9381	0.0000	0.0000
186.420	.292197	3280546.	52818.8680	-	0043069	19726.1600	0.0000	0.0000
191.200	.272455	3539494.	51961.1338	-	0040712	1335.2884	-1068.8240	18751.6725
195.980	.253276	3777295.	47164.5094	-	0039492	1424.9999	-1081.4525	20409.8833
200.760	.234700	3990386.	41968.9883	-	0038197	1505.3895	-1092.4057	22248.3556
205.540	.216761	4178518.	36725.2205	-	0036834	1576.3631	-1101.6393	24293.3321
210.320	.199487	4341479.	31441.5359	-	0035414	1637.8409	-1109.1074	26575.8733
215.100	.182905	4479099.	26126.4884	-	0033943	1689.7585	-1114.7619	29132.9668
219.880	.167037	4591249.	20788.8671	-	0032431	1732.0673	-1118.5524	32008.9507
224.660	.151901	4677841.	15437.7110	-	0030885	1764.7346	-1120.4250	35257.3660
229.440	.137511	4738833.	10082.3275	-	0029315	1787.7442	-1120.3212	38943.3958
234.220	.123876	4774228.	5388.8914	-	0027729	1801.0970	-843.4596	32546.6068
239.000	.111002	4790351.	1366.1401	-	0026134	1807.1795	-839.7000	36159.4416
243.780	.098892	4787288.	-2634.7734	-	0024537	1806.0240	-834.3225	40327.6286
248.560	.087544	4765162.	-6605.9531	-	0022944	1797.6770	-827.2590	45169.1027
253.340	.076957	4724135.	-10539.1558	-	0021362	1782.1994	-818.4325	50835.2045
258.120	.067122	4664408.	-14425.7415	-	0019797	1759.6671	-807.7540	57523.0463
262.900	.058031	4586225.	-18256.6065	-	0018254	1730.1722	-795.1184	65493.7867
267.680	.049671	4489875.	-22022.0918	-	0016741	1693.8237	-780.3985	75100.4205
272.460	.042027	4375694.	-25711.8570	-	0015263	1650.7484	-763.4364	86831.4728
277.240	.035080	4244070.	-29314.7021	-	0013826	1601.0926	-744.0302	101382.
282.020	.028809	4095445.	-32818.3059	-	0012435	1545.0235	-721.9128	119779.
286.800	.023192	3930327.	-36208.8293	-	0011097	1482.7318	-696.7163	143598.
291.580	.018201	3749289.	-39470.2850	-	0009816	1414.4346	-667.9095	175410.
296.360	.013807	3552991.	-42583.4700	-	0008599	1340.3803	-634.6783	219720.
301.140	.009980	3342191.	-45524.0053	-	0007449	1260.8552	-595.6712	285291.
305.920	.006686	3117781.	-48258.2761	-	0006372	1176.1957	-548.3752	392042.
310.700	.003889	2880842.	-50733.2426	-	0005372	1086.8094	-487.1756	598821.
315.480	.001551	2632771.	-52838.6981	-	0004452	993.2238	-393.7682	1213764.
320.260	.000368	2375704.	-53247.5095	-	0003617	896.2440	222.7174	2895341.
325.040	.001907	2123725.	-51691.5951	-	0002867	801.1840	428.2928	1073308.
329.820	.003109	1881532.	-49492.6468	-	0002199	709.8158	491.7692	756177.
334.600	.004010	1650575.	-47044.8216	-	0001610	622.6864	532.4255	634680.
339.380	.004648	1431784.	-44431.3071	-	0001096	540.1463	561.0952	577023.
344.160	.005058	1225812.	-41699.5417	-6.	5323E-05	462.4427	581.9028	549921.
348.940	.005273	1033136.	-38882.2193	-2.	7658E-05	389.7548	596.8932	541134.
353.720	.005322	854098.	-36004.3537	3.	8099E-06	322.2120	607.2347	545352.
358.500	.005236	688935.	-33086.4230	2.	9538E-05	259.9034	613.6568	560201.
363.280	.005040	537792.	-30146.0093	4.	9992E-05	202.8842	616.6419	584829.
368.060	.004758	400739.	-27198.7486	6.	5641E-05	151.1803	616.5216	619348.
372.840	.004412	277772.	-24258.9277	7.	6955E-05	104.7906	613.5290	664630.
377.620	.004023	168823.	-21339.8844	8.	4401E-05	63.6893	607.8281	722291.
382.400	.003606	73762.6512	-18454.2950	8.	8446E-05	27.8273	599.5315	794806.
387.180	.003177	-7599.7113	-15614.3980	8.	9549E-05	2.8670	588.7099	885764.
391.960	.002750	-75510.9938	-12832.1863	8.	8163E-05	28.4868	575.3954	1000317.
396.740	.002334	-130275.	-10119.5982	8.	4732E-05	49.1469	559.5787	1145953.
401.520	.001939	-172254.	-7488.7404	7.	9688E-05	64.9837	541.1986	1333828.

B-029 - Pile and Lagging - 15.8 ft Wall Ht. Ipo							
406.300	-.001572	-201868.	-4952.1919	7.3450E-05	76.1554	520.1187	1581232.
411.080	-.001237	-219597.	-2523.4798	6.6422E-05	82.8440	496.0788	1916481.
415.860	-.000937	-225992.	-217.9108	5.8993E-05	85.2565	468.5944	2389716.
420.640	-.000673	-221681.	1945.8131	5.1528E-05	83.6299	436.7294	3100377.
425.420	-.000445	-207390.	3865.6207	4.4374E-05	78.2388	366.5373	3939935.
430.200	-.000249	-184725.	5238.2999	3.7836E-05	69.6883	207.8054	3987419.
434.980	-8.30E-05	-157312.	5902.3588	3.2133E-05	59.3466	70.0435	4034903.
439.760	5.81E-05	-128299.	5951.2115	2.7371E-05	48.4012	-49.6030	4082387.
444.540	.000179	-100419.	5463.6862	2.3557E-05	37.8833	-154.3825	4129871.
449.320	.000283	-76065.8111	4853.8325	2.0614E-05	28.6961	-100.7865	1700618.
454.100	.000376	-54015.8966	4293.4415	1.8445E-05	20.3777	-133.6868	1700618.
458.880	.000460	-35020.5105	3583.1085	1.6961E-05	13.2116	-163.5237	1700618.
463.660	.000538	-19761.3796	2734.9015	1.6047E-05	7.4551	-191.3746	1700618.
468.440	.000613	-8874.8518	1832.0631	1.5570E-05	3.3481	-186.3821	1453268.
473.220	.000687	-2246.8559	928.3318	1.5385E-05	.8476356	-191.7482	1334623.
478.000	.000760	0.0000	0.0000	1.5347E-05	0.0000	-196.6751	618400.

Output Veri fication:

Computed forces and moments are withi n speci fied convergence l i m i t s.

Output Summary for Load Case No. 1:

Pile-head deflection	=	1.60940262 in
Computed slope at pile head	=	-.00775354
Maximum bending moment	=	4790351. lbs-in
Maximum shear force	=	-53247.50952 lbs
Depth of maximum bending moment	=	239.00000 in
Depth of maximum shear force	=	320.26000 in
Number of iterations	=	26
Number of zero deflection points	=	2

Summary of Pile Response(s)

Defi n i t i o n of Symbols for Pile-Head Loading Condi t i o n s:

Type 1 = Shear and Moment,	y = pile-head displacement in
Type 2 = Shear and Slope,	M = Pile-head Moment lbs-in
Type 3 = Shear and Rot. Stiffness,	V = Pile-head Shear Force lbs
Type 4 = Deflection and Moment,	S = Pile-head Slope, radians
Type 5 = Deflection and Slope,	R = Rot. Stiffness of Pile-head in-lbs/rad

Load Type	Pile-Head Condition 1	Pile-Head Condition 2	Axial Load lbs	Pile-Head Deflection in	Maximum Moment in-lbs	Maximum Shear lbs
1	V= 0.000	M= 0.000	0.0000	1.6094	4790351.	-53247.5095

Pile-head Deflection vs. Pile Length

Boundary Condi t i o n Type 1, Shear and Moment

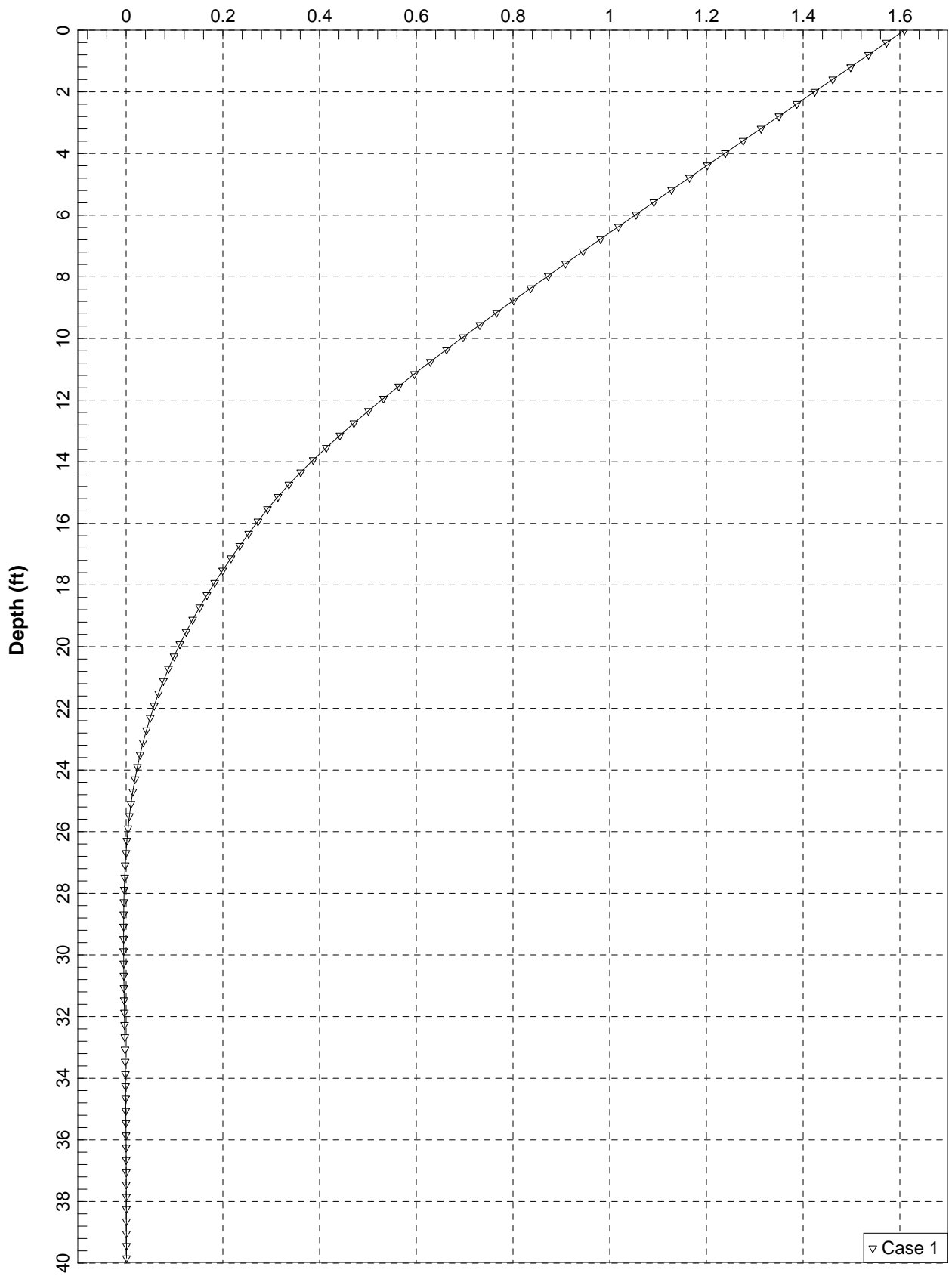
Shear	=	0. lbs
Moment	=	0. in-lbs
Axial Load	=	0. lbs

Pile Length in	Pile Head Deflection in	Maximum Moment in-lbs	Maximum Shear lbs
478.000	1.60940262	4790351.	-53247.50952
454.100	1.59445853	4773473.	-52997.58942
430.200	1.69668301	4911590.	54038.52137
406.300	1.61243990	4793546.	53088.85421
382.400	1.75448196	4745815.	-58622.31002
358.500	2.23895532	4549885.	-63439.04817
334.600	4.30607957	4383199.	-69283.36899

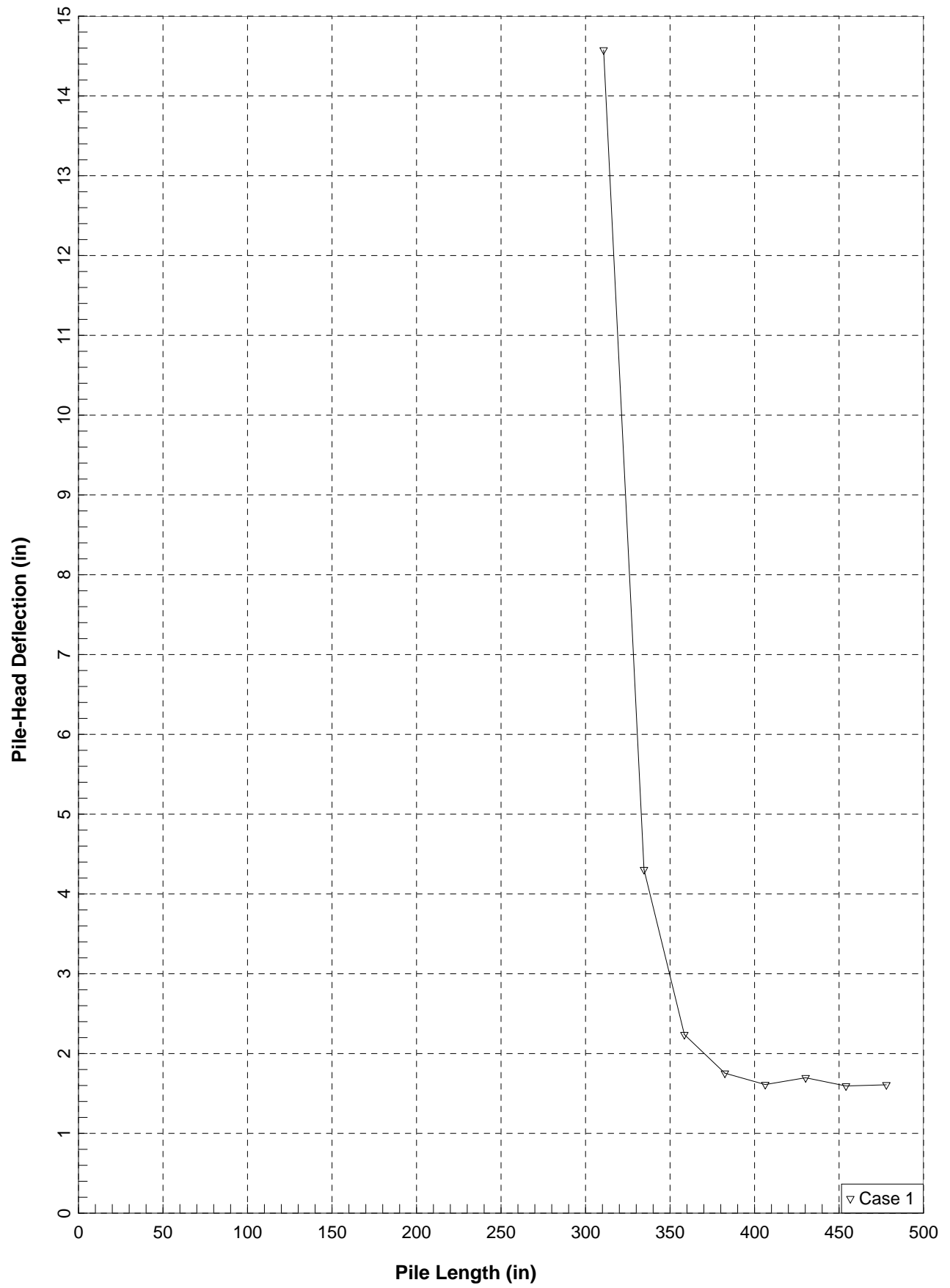
310.700 14.57644004 B-029 - Pile and Lagging - 15.8 ft Wall Ht. Ipo
4245515. -78254.70155

The analysis ended normally.

Lateral Deflection (in)



▽ Case 1



LPILE Plus for Windows, Version 5.0 (5.0.39)

Analysis of Individual Piles and Drilled Shafts
Subjected to Lateral Loading Using the p-y Method

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This program is licensed to:

Path to file locations: J:\GEOTECH\Projects\2010\B-10-020 HAM-75-7.85\HAM-75-7.85 PID 77889 -
Mainline\Analysis\Retaining Wall U\B-029 - Pile and Lagging - 15.8 ft Wall Ht\
Name of input data file: B-029 - Pile and Lagging - 15.8 ft Wall Ht.lpd
Name of output file: B-029 - Pile and Lagging - 15.8 ft Wall Ht.lpo
Name of plot output file: B-029 - Pile and Lagging - 15.8 ft Wall Ht.lpp
Name of runtime file: B-029 - Pile and Lagging - 15.8 ft Wall Ht.lpr

Time and Date of Analysis

Date: August 8, 2013 Time: 14:37:10

Problem Title

HAM-75-7.85 - Retaining Wall U - B-029-0-11 - 15.8 ft Wall Height - Strength

Program Options

Units Used in Computations - US Customary Units: Inches, Pounds

Basic Program Options:

Analysis Type 1:

- Computation of Lateral Pile Response Using User-specified Constant EI

Computation Options:

- Only internally-generated p-y curves used in analysis
- Analysis uses p-y multipliers for group action
- Analysis assumes no shear resistance at pile tip
- Analysis includes automatic computation of pile-top deflection vs. pile embedment length
- No computation of foundation stiffness matrix elements
- Output pile response for full length of pile
- Analysis assumes no soil movements acting on pile
- No additional p-y curves to be computed at user-specified depths

Solution Control Parameters:

- Number of pile increments = 100
- Maximum number of iterations allowed = 100
- Deflection tolerance for convergence = 1.0000E-05 in
- Maximum allowable deflection = 1.0000E+02 in

Printing Options:

- Values of pile-head deflection, bending moment, shear force, and soil reaction are printed for full length of pile.
- Printing Increment (spacing of output points) = 1

Pile Structural Properties and Geometry

Pile Length = 478.00 in

B-029 - Pile and Lagging - 15.8 ft Wall Ht. I po

Depth of ground surface below top of pile = 190.00 in

Slope angle of ground surface = .00 deg.

Structural properties of pile defined using 4 points

Point	Depth X in	Pile Diameter in	Moment of Inertia in**4	Pile Area Sq. in	Modulus of Elasti ci ty lbs/Sq. in
1	0.0000	18.40000000	1530.0000	25.3000	29000000.
2	190.0000	18.40000000	1530.0000	25.3000	29000000.
3	190.0000	30.00000000	39761.0000	706.9000	3604997.
4	478.0000	30.00000000	39761.0000	706.9000	3604997.

Soil and Rock Layering Information

The soil profile is modelled using 3 layers

Layer 1 is stiff clay without free water
Distance from top of pile to top of layer = 190.000 in
Distance from top of pile to bottom of layer = 232.000 in

Layer 2 is stiff clay without free water
Distance from top of pile to top of layer = 232.000 in
Distance from top of pile to bottom of layer = 448.000 in

Layer 3 is stiff clay without free water
Distance from top of pile to top of layer = 448.000 in
Distance from top of pile to bottom of layer = 650.000 in

(Depth of lowest layer extends 172.00 in below pile tip)

Effective Unit Weight of Soil vs. Depth

Effective unit weight of soil with depth defined using 6 points

Point No.	Depth X in	Eff. Uni t Weight lbs/in**3
1	190.00	.07200
2	232.00	.07200
3	232.00	.06900
4	448.00	.06900
5	448.00	.06700
6	650.00	.06700

Shear Strength of Soils

Shear strength parameters with depth defined using 6 points

Point No.	Depth X in	Cohesi on c lbs/in**2	Angle of Fricti on Deg.	E50 or k_rm	RQD %
1	190.000	27.80000	.00	.00400	.0
2	232.000	27.80000	.00	.00400	.0
3	232.000	20.80000	.00	.00500	.0
4	448.000	20.80000	.00	.00500	.0
5	448.000	8.60000	.00	.00700	.0
6	650.000	8.60000	.00	.00700	.0

Notes:

- (1) Cohesion = uniaxial compressive strength for rock materials.
- (2) Values of E50 are reported for clay strata.
- (3) Default values will be generated for E50 when input values are 0.
- (4) RQD and k_rm are reported only for weak rock strata.

 p-y Modification Factors

Distribution of p-y multipliers with depth defined using 2 points

Point No.	Depth X in	p-mult	y-mult
1	190.000	.8685	1.0000
2	650.000	.8685	1.0000

 Loading Type

Static loading criteria was used for computation of p-y curves.

 Distributed Lateral Loading

Distributed lateral load intensity defined using 2 points

Point No.	Depth X in	Dist. Load lbs/in
1	.000	.00000
2	190.000	866.30000

 Pile-head Loading and Pile-head Fixity Conditions

Number of loads specified = 1

Load Case Number 1

Pile-head boundary conditions are Shear and Moment (BC Type 1)

Shear force at pile head = .000 lbs
 Bending moment at pile head = .000 in-lbs
 Axial load at pile head = .000 lbs

(Zero moment at pile head for this load indicates a free-head condition)

 Computed Values of Load Distribution and Deflection
 for Lateral Loading for Load Case Number 1

Pile-head boundary conditions are Shear and Moment (BC Type 1)

Specified shear force at pile head = .000 lbs
 Specified moment at pile head = .000 in-lbs
 Specified axial load at pile head = .000 lbs

(Zero moment for this load indicates free-head conditions)

Depth X in	Deflect. y in	Moment M lbs-in	Shear V lbs	Slope S Rad.	Total Stress lbs/in**2	Soil Res. p lbs/in	Es*h F/L lbs/in
0.000	2.902	-1.6385E-05	0.0000	-.0131566	9.8527E-08	0.0000	0.0000
4.780	2.839	31.1228	58.5994	-.0131566	.1871434	0.0000	0.0000
9.560	2.776	560.2101	214.8644	-.0131565	3.3686	0.0000	0.0000
14.340	2.713	2085.2264	475.3061	-.0131564	12.5386	0.0000	0.0000
19.120	2.650	5104.1363	839.9245	-.0131560	30.6915	0.0000	0.0000
23.900	2.587	10114.9044	1308.7195	-.0131552	60.8216	0.0000	0.0000

B-029 - Pile and Lagging - 15.8 ft Wall Ht. I po

28.680	2.524	17615.4950	1881.6913	-0.131537	105.9232	0.0000	0.0000
33.460	2.461	28103.8728	2558.8397	-0.131512	168.9906	0.0000	0.0000
38.240	2.399	42078.0022	3340.1648	-0.131475	253.0181	0.0000	0.0000
43.020	2.336	60035.8478	4225.6665	-0.131420	360.9999	0.0000	0.0000
47.800	2.273	82475.3742	5215.3450	-0.131343	495.9304	0.0000	0.0000
52.580	2.210	109895.	6309.2001	-0.131239	660.8038	0.0000	0.0000
57.360	2.147	142791.	7507.2319	-0.131103	858.6145	0.0000	0.0000
62.140	2.085	181664.	8809.4404	-0.130928	1092.3568	0.0000	0.0000
66.920	2.022	227010.	10215.8255	-0.130708	1365.0249	0.0000	0.0000
71.700	1.960	279327.	11726.3874	-0.130435	1679.6132	0.0000	0.0000
76.480	1.898	339114.	13341.1259	-0.130102	2039.1159	0.0000	0.0000
81.260	1.835	406868.	15060.0411	-0.129700	2446.5274	0.0000	0.0000
86.040	1.774	483088.	16883.1330	-0.129221	2904.8419	0.0000	0.0000
90.820	1.712	568271.	18810.4015	-0.128655	3417.0537	0.0000	0.0000
95.600	1.651	662915.	20841.8467	-0.127992	3986.1572	0.0000	0.0000
100.380	1.590	767519.	22977.4687	-0.127221	4615.1466	0.0000	0.0000
105.160	1.529	882580.	25217.2672	-0.126332	5307.0162	0.0000	0.0000
109.940	1.469	1008596.	27561.2425	-0.125314	6064.7604	0.0000	0.0000
114.720	1.409	1146065.	30009.3945	-0.124153	6891.3733	0.0000	0.0000
119.500	1.350	1295486.	32561.7231	-0.122838	7789.8494	0.0000	0.0000
124.280	1.292	1457355.	35218.2284	-0.121355	8763.1829	0.0000	0.0000
129.060	1.234	1632172.	37978.9104	-0.119691	9814.3681	0.0000	0.0000
133.840	1.177	1820434.	40843.7690	-0.117831	10946.3994	0.0000	0.0000
138.620	1.121	2022639.	43812.8044	-0.115761	12162.2709	0.0000	0.0000
143.400	1.067	2239284.	46886.0164	-0.113465	13464.9770	0.0000	0.0000
148.180	1.013	2470869.	50063.4051	-0.110928	14857.5120	0.0000	0.0000
152.960	.960611	2717890.	53344.9704	-0.108133	16342.8702	0.0000	0.0000
157.740	.909623	2980847.	56730.7125	-0.105064	17924.0459	0.0000	0.0000
162.520	.860170	3260236.	60220.6312	-0.101702	19604.0333	0.0000	0.0000
167.300	.812396	3556556.	63814.7266	-0.098030	21385.8269	0.0000	0.0000
172.080	.766454	3870305.	67512.9987	-0.094029	23272.4208	0.0000	0.0000
176.860	.722504	4201980.	71315.4475	-0.089681	25266.8094	0.0000	0.0000
181.640	.680718	4552080.	75222.0729	-0.084966	27371.9870	0.0000	0.0000
186.420	.641277	4921103.	79232.8751	-0.079863	29590.9478	0.0000	0.0000
191.200	.604369	5309547.	78660.6647	-0.076327	2003.0482	-1304.3891	10316.5067
195.980	.568308	5673099.	72893.6285	-0.074496	2140.1999	-1323.5902	11132.6253
200.760	.533151	6006410.	66524.9765	-0.072548	2265.9427	-1341.1177	12023.8725
205.540	.498952	6309078.	60076.6399	-0.070495	2380.1255	-1356.9311	12999.5126
210.320	.465758	6580742.	53556.9114	-0.068346	2482.6120	-1370.9888	14070.2372
215.100	.433613	6821082.	46974.2850	-0.066111	2573.2811	-1383.2481	15248.4395
219.880	.402556	7029817.	40337.4636	-0.063802	2652.0271	-1393.6646	16548.5540
224.660	.372619	7206708.	33655.3675	-0.061428	2718.7602	-1402.1915	17987.4805
229.440	.343831	7351562.	26937.1468	-0.059000	2773.4068	-1408.7795	19585.1177
234.220	.316214	7464227.	21022.1055	-0.056530	2815.9103	-1066.1332	16116.0133
239.000	.289788	7552533.	15923.0628	-0.054026	2849.2241	-1067.3575	17605.8670
243.780	.264565	7616452.	10821.8831	-0.051497	2873.3376	-1067.0273	19278.3741
248.560	.240557	7655991.	5726.1188	-0.048950	2888.2538	-1065.0916	21163.9670
253.340	.217769	7671194.	643.5762	-0.046395	2893.9892	-1061.4953	23299.7041
258.120	.196203	7662143.	-4417.6630	-0.043838	2890.5748	-1056.1780	25731.1071
262.900	.175859	7628961.	-9449.2131	-0.041289	2878.0566	-1049.0731	28514.6437
267.680	.156732	7571809.	-14442.3485	-0.038754	2856.4958	-1040.1049	31721.1300
272.460	.138811	7490892.	-19387.9566	-0.036242	2825.9696	-1029.1872	35440.4838
277.240	.122084	7386460.	-24276.4778	-0.033762	2786.5722	-1016.2192	39788.4968
282.020	.106534	7258809.	-29097.8261	-0.031320	2738.4153	-1001.0814	44916.7147
286.800	.092142	7108285.	-33841.2833	-0.028924	2681.6294	-983.6288	51027.2466
291.580	.078883	6935286.	-38495.3555	-0.026583	2616.3650	-963.6818	58395.6674
296.360	.066729	6740269.	-43047.5725	-0.024303	2542.7940	-941.0115	67407.7797
301.140	.055649	6523751.	-47484.2003	-0.022091	2461.1119	-915.3181	78621.2865
305.920	.045610	6286320.	-51789.8154	-0.019955	2371.5399	-886.1945	92874.9816
310.700	.036572	6028641.	-55946.6446	-0.017902	2274.3293	-853.0646	111495.
315.480	.028496	5751470.	-59933.4867	-0.015937	2169.7656	-815.0702	136723.
320.260	.021336	5455676.	-63723.8211	-0.014069	2058.1763	-770.8437	172694.
325.040	.015046	5142270.	-67282.1355	-0.012302	1939.9425	-717.9908	228098.
329.820	.009576	4812459.	-70555.6301	-0.010642	1815.5200	-651.6722	325299.
334.600	.004873	4467759.	-73449.6364	-0.009094	1685.4802	-559.2091	548588.
339.380	.000881	4110281.	-75672.4925	-0.007664	1550.6202	-370.8562	2011062.
344.160	-.002454	3744329.	-75398.6228	-0.006355	1412.5636	485.4461	945413.
348.940	-.005193	3389470.	-72817.4777	-0.005165	1278.6914	594.5309	547201.
353.720	-.007392	3048194.	-69821.2190	-0.004092	1149.9438	659.1338	426215.
358.500	-.009105	2721979.	-66561.8337	-0.003130	1026.8777	704.6258	369917.
363.280	-.010384	2411863.	-63112.1997	-0.002274	909.8853	738.7357	340058.
368.060	-.011279	2118626.	-59518.4089	-0.001518	799.2605	764.9425	324194.
372.840	-.011835	1842867.	-55813.7394	-8.5757E-05	695.2292	785.1284	317095.
377.620	-.012098	1585047.	-52024.2591	-2.8600E-05	597.9655	800.4282	316246.
382.400	-.012109	1345515.	-48171.5729	2.0264E-05	507.6012	811.5744	320375.
387.180	-.011905	1124527.	-44274.3570	6.1449E-05	424.2323	819.0599	328873.
391.960	-.011521	922252.	-40349.3019	9.5576E-05	347.9235	823.2226	341543.
396.740	-.010991	738787.	-36411.7445	.0001233	278.7106	824.2909	358488.
401.520	-.010343	574156.	-32476.1311	.0001452	216.6028	822.4092	380083.

B-029 - Pile and Lagging - 15.8 ft Wall Ht. Ipo								
406.300	-	.009603	428316.	-28556.3923	.0001619	161.5838	817.6489	406988.
411.080	-	.008795	301157.	-24666.2874	.0001740	113.6128	810.0101	440222.
415.860	-	.007939	192506.	-20819.7648	.0001823	72.6237	799.4136	481302.
420.640	-	.007053	102120.	-17031.3906	.0001872	38.5252	785.6802	532499.
425.420	-	.006150	29685.8803	-13316.9208	.0001894	11.1991	768.4913	597318.
430.200	-	.005242	-25189.6030	-9694.1369	.0001895	9.5029	747.3179	681430.
434.980	-	.004339	-62990.0682	-6184.1769	.0001880	23.7633	721.2846	794671.
439.760	-	.003445	-84310.3343	-2813.8571	.0001855	31.8064	688.8911	955845.
444.540	-	.002565	-89890.5416	379.7821	.0001826	33.9116	647.3596	1206439.
449.320	-	.001699	-80679.6177	2501.7596	.0001798	30.4367	240.4971	676583.
454.100	-	.000846	-65973.7201	3559.4249	.0001773	24.8889	202.0407	1141345.
458.880	-3.74E-06	-46651.5154	4045.4787	.0001755	17.5995	1.3290	1700618.	
463.660	.000831	-27298.9440	3568.0121	.0001742	10.2986	-201.1059	1156438.	
468.440	.001662	-12541.3199	2515.8102	.0001736	4.7313	-239.1460	687847.	
473.220	.002491	-3247.7989	1311.8535	.0001733	1.2252	-264.6016	507846.	
478.000	.003319	0.0000	0.0000	.0001732	0.0000	-284.2911	204740.	

Output Veri fication:

Computed forces and moments are withi n speci fied convergence l imi ts.

Output Summary for Load Case No. 1:

Pile-head deflection	=	2.90160147 in
Computed slope at pile head	=	-.01315658
Maximum bending moment	=	7671194. lbs-in
Maximum shear force	=	79232.87506 lbs
Depth of maximum bending moment	=	253.34000 in
Depth of maximum shear force	=	186.42000 in
Number of iterations	=	31
Number of zero deflection points	=	2

Summary of Pile Response(s)

Defini tion of Symbols for Pile-Head Loading Condi ti ons:

Type 1 = Shear and Moment,	y = pile-head displacement in
Type 2 = Shear and Slope,	M = Pile-head Moment lbs-in
Type 3 = Shear and Rot. Stiffness,	V = Pile-head Shear Force lbs
Type 4 = Deflection and Moment,	S = Pile-head Slope, radians
Type 5 = Deflection and Slope,	R = Rot. Stiffness of Pile-head in-lbs/rad

Load Type	Pile-Head Condition 1	Pile-Head Condition 2	Axial Load lbs	Pile-Head Deflection in	Maximum Moment in-lbs	Maximum Shear lbs
1	V=	0.000 M=	0.000	2.9016	7671194.	79232.8751

Pile-head Deflection vs. Pile Length

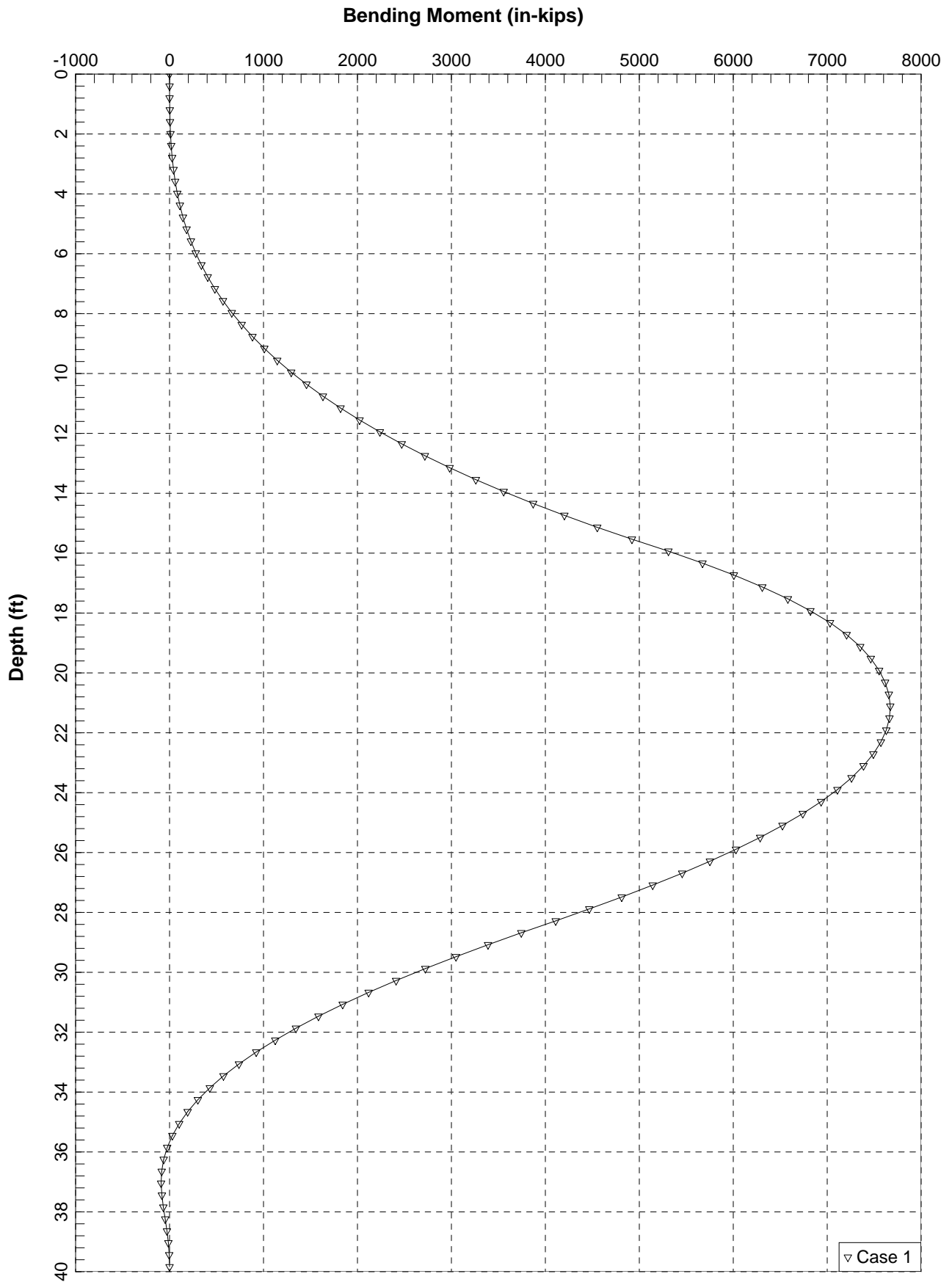
Boundary Condi tion Type 1, Shear and Moment

Shear	=	0. lbs
Moment	=	0. in-lbs
Axial Load	=	0. lbs

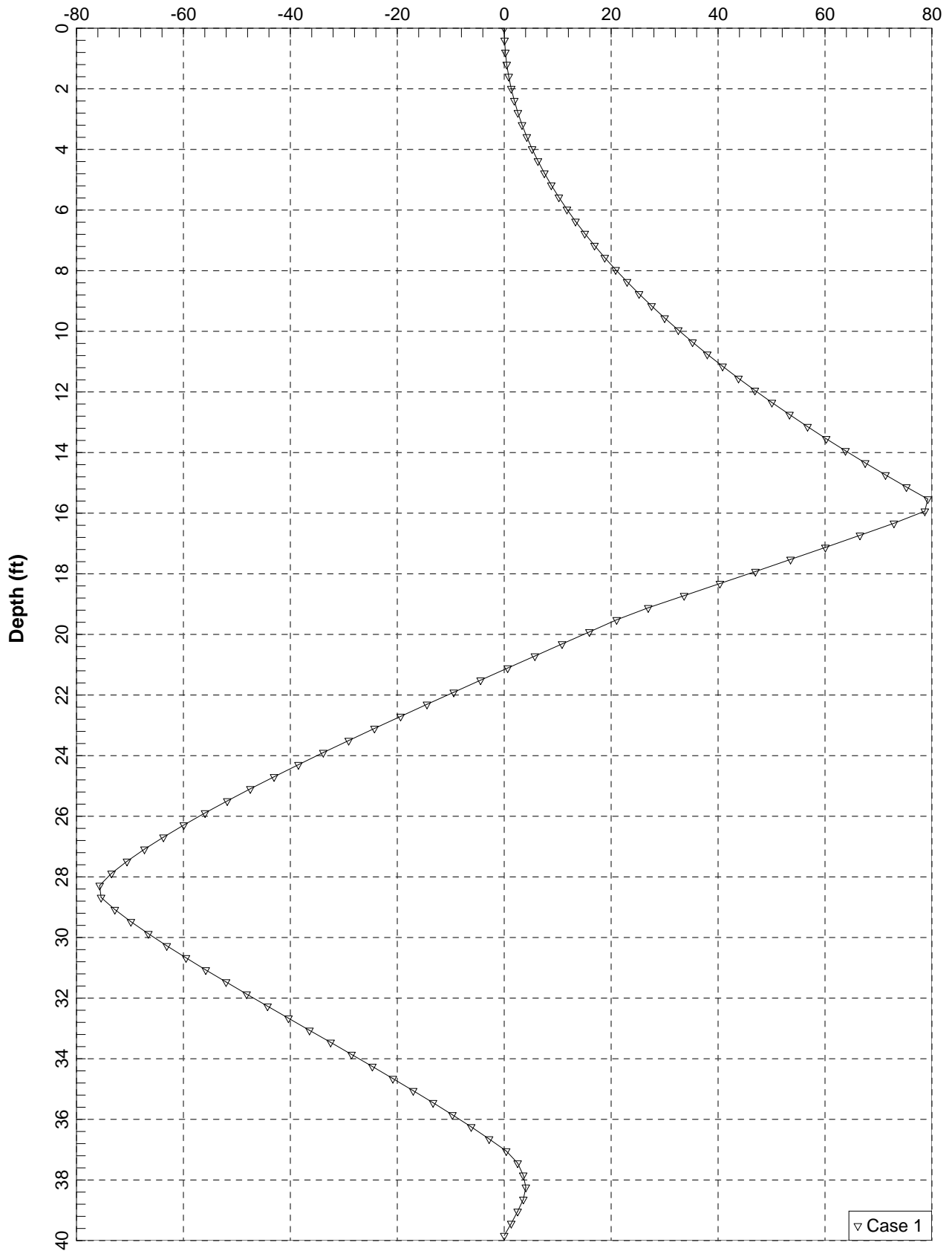
Pile Length in	Pile Head Deflection in	Maximum Moment in-lbs	Maximum Shear lbs
478.000	2.90160147	7671194.	79232.87506
454.100	2.87292254	7637214.	79029.22581
430.200	3.10655594	7825995.	81062.46071
406.300	3.24807165	7503985.	-85106.31073
382.400	4.47057707	7246895.	-92058.97332
358.500	7.47807286	6863173.	-96806.93734
334.600	18.75881664	6603005.	-104858.96195

B-029 - Pile and Lagging - 15.8 ft Wall Ht. Ipo

The analysis ended normally.

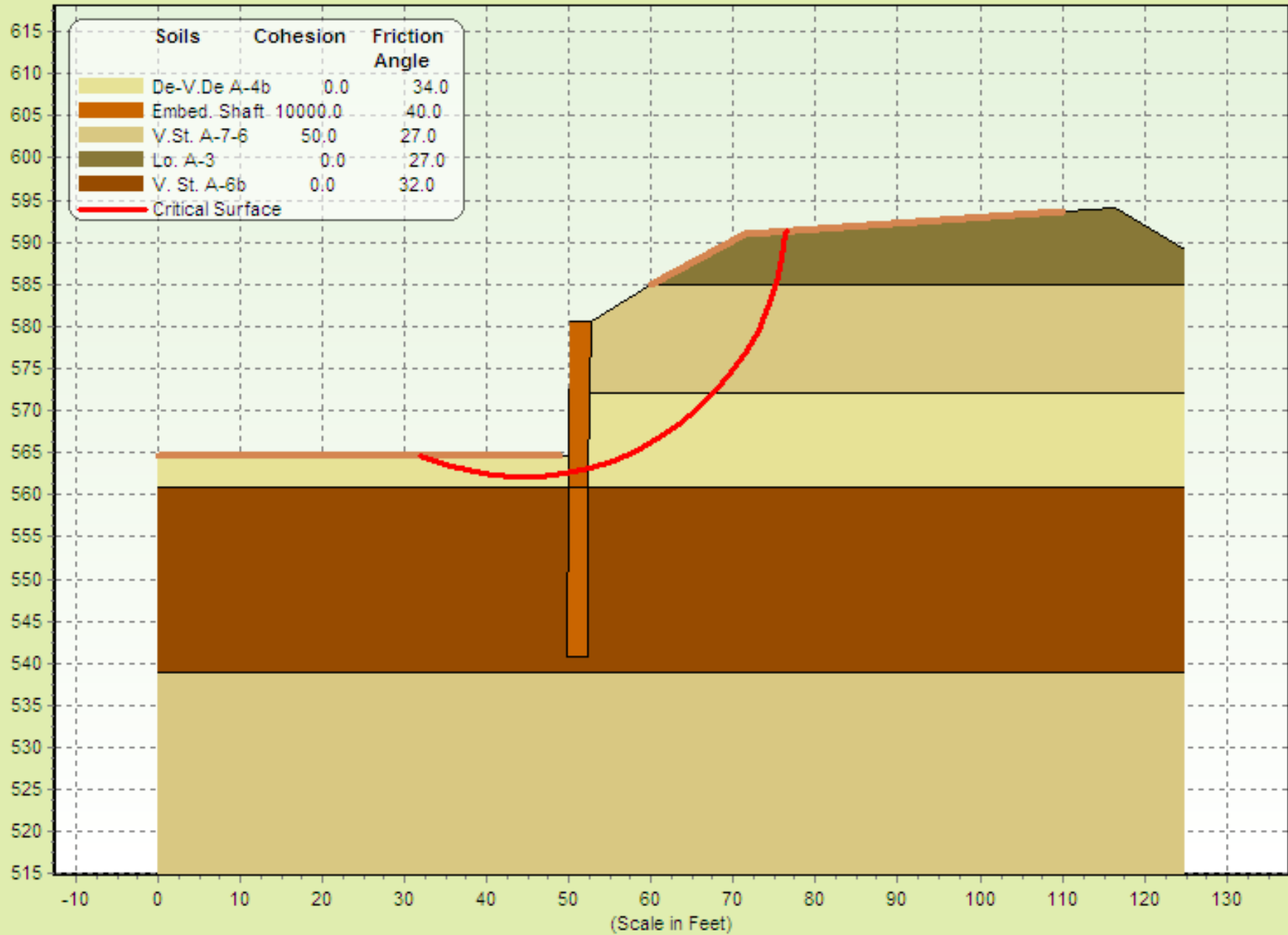


Shear Force (kips)



▽ Case 1

Problem: B-10-020 - HAM-75-7.85 - Wall U - Sta. 469+50 - Pile and Lagging Wall - FS Min- Janbu = 1.817



result.out
 ** STABL for WINDOWS **
 by
 Geotechnical Software Solutions

1

--Slope Stability Analysis--
 Simplified Janbu, Simplified Bishop
 or Spencer's Method of Slices

Run Date:
 Time of Run:
 Run By:
 Input Data Filename: run.in
 Output Filename: result.out
 Unit: U.S.C.
 Plotted Output Filename: result.plt

PROBLEM DESCRIPTION B-10-020 - HAM-75-7.85 - Wall U - Sta. 4
 69+50 - Pile and Lagging Wall

BOUNDARY COORDINATES

7 Top Boundaries
 19 Total Boundaries

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	0.00	564.70	50.00	564.70	3
2	50.00	564.70	50.20	580.50	5
3	50.20	580.50	52.70	580.50	5
4	52.70	580.50	60.00	585.00	2
5	60.00	585.00	71.50	591.00	1
6	71.50	591.00	116.50	594.00	1
7	116.50	594.00	125.00	589.00	1
8	60.00	585.00	125.00	585.00	2
9	52.60	572.00	52.70	580.50	2
10	52.60	572.00	125.00	572.00	3
11	0.00	561.00	49.90	561.00	4
12	49.90	561.00	50.00	564.70	5
13	49.90	561.00	52.40	561.00	5
14	52.40	561.00	52.60	572.00	3
15	52.40	561.00	125.00	561.00	4
16	49.80	540.70	49.90	561.00	5
17	49.80	540.70	52.30	540.70	4
18	52.30	540.70	52.40	561.00	4
19	0.00	539.00	125.00	539.00	2

1

ISOTROPIC SOIL PARAMETERS

5 Type(s) of Soil

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	120.0	125.0	0.0	27.0	0.00	0.0	1
2	120.0	130.0	50.0	27.0	0.00	0.0	1
3	135.0	140.0	0.0	34.0	0.00	0.0	1
4	120.0	130.0	0.0	32.0	0.00	0.0	1
5	140.0	140.0	10000.0	40.0	0.00	0.0	1

1

A Critical Failure Surface Searching Method, Using A Random Technique For Generating Circular Surfaces, Has Been Specified.

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500 Trial Surfaces Have Been Generated.

10 Surfaces Initiate From Each Of 50 Points Equally Spaced
Along The Ground Surface Between X = 0.00 ft.
and X = 49.00 ft.

Each Surface Terminates Between X = 60.00 ft.
and X = 110.00 ft.

Unless Further Limitations Were Imposed, The Minimum Elevation
At Which A Surface Extends Is Y = 500.00 ft.

3.00 ft. Line Segments Define Each Trial Failure Surface.

1

Following Are Displayed The Ten Most Critical Of The Trial
Failure Surfaces Examined. They Are Ordered - Most Critical
First.

* * Safety Factors Are Calculated By The Modified Janbu Method * *

Failure Surface Specified By 22 Coordinate Points

Poi nt No.	X-Surf (ft)	Y-Surf (ft)
1	32.00	564.70
2	34.82	563.66
3	37.72	562.89
4	40.67	562.40
5	43.67	562.18
6	46.67	562.24
7	49.65	562.59
8	52.58	563.21
9	55.45	564.10
10	58.21	565.25
11	60.86	566.66
12	63.37	568.31
13	65.71	570.19
14	67.86	572.28
15	69.81	574.56
16	71.54	577.01
17	73.03	579.61
18	74.28	582.34
19	75.26	585.18
20	75.97	588.09
21	76.41	591.06
22	76.43	591.33

*** 1.817 ***

Individual data on the 31 slices

Slice No.	Width (ft)	Weight (lbs)	Water Force Top (lbs)	Water Force Bot (lbs)	Force Norm (lbs)	Force Tan (lbs)	Earthquake Force Hor (lbs)	Earthquake Force Ver (lbs)	Surcharge Load (lbs)
1	2.8	197.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	2.9	556.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	3.0	820.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	3.0	973.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	3.0	1007.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	3.0	919.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0

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7	0.3	84.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.1	15.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.2	277.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	2.2	5505.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.1	339.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	45.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.1	228.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14	2.7	6165.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	2.8	6407.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	1.8	4180.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	0.9	2016.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18	2.5	5766.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	2.3	5184.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	1.9	3920.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	0.3	580.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	2.0	3790.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	1.7	2996.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	0.0	71.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25	1.5	2282.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26	1.2	1516.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27	0.9	834.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28	0.1	45.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29	0.7	397.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30	0.4	91.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
31	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Failure Surface Specified By 23 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	28.00	564.70
2	30.86	563.81
3	33.79	563.13
4	36.75	562.68
5	39.74	562.44
6	42.74	562.44
7	45.74	562.65
8	48.70	563.09
9	51.63	563.76
10	54.50	564.64
11	57.29	565.73
12	60.00	567.03
13	62.60	568.52
14	65.08	570.21
15	67.42	572.08
16	69.62	574.12
17	71.67	576.32
18	73.54	578.66
19	75.23	581.14
20	76.73	583.74
21	78.03	586.44
22	79.12	589.23
23	79.84	591.56

*** 1.834 ***

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Failure Surface Specified By 21 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	35.00	564.70
2	37.93	564.04
3	40.90	563.62
4	43.89	563.43
5	46.89	563.47
6	49.88	563.75
7	52.83	564.26
8	55.74	565.01
9	58.58	565.97
10	61.33	567.16

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11	63.99	568.56
12	66.52	570.17
13	68.92	571.97
14	71.17	573.95
15	73.26	576.10
16	75.18	578.41
17	76.91	580.86
18	78.44	583.44
19	79.76	586.14
20	80.87	588.93
21	81.72	591.68

*** 1.841 ***

Failure Surface Specified By 23 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	30.00	564.70
2	32.66	563.31
3	35.44	562.19
4	38.32	561.35
5	41.27	560.79
6	44.26	560.51
7	47.26	560.53
8	50.24	560.84
9	53.18	561.44
10	56.05	562.32
11	58.82	563.48
12	61.46	564.90
13	63.95	566.57
14	66.27	568.47
15	68.40	570.59
16	70.30	572.90
17	71.98	575.39
18	73.40	578.03
19	74.56	580.80
20	75.45	583.67
21	76.05	586.60
22	76.37	589.59
23	76.38	591.33

*** 1.842 ***

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Failure Surface Specified By 19 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	39.00	564.70
2	41.92	564.03
3	44.90	563.64
4	47.90	563.56
5	50.89	563.77
6	53.85	564.28
7	56.74	565.08
8	59.54	566.16
9	62.21	567.51
10	64.74	569.12
11	67.10	570.98
12	69.26	573.06
13	71.21	575.34
14	72.92	577.81
15	74.38	580.43
16	75.57	583.18
17	76.48	586.04
18	77.10	588.98

result.out

19 77.37 591.39
*** 1.852 ***

Failure Surface Specified By 23 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	29.00	564.70
2	31.94	564.10
3	34.91	563.68
4	37.90	563.46
5	40.90	563.44
6	43.90	563.61
7	46.88	563.97
8	49.82	564.52
9	52.73	565.26
10	55.58	566.19
11	58.37	567.30
12	61.08	568.59
13	63.70	570.05
14	66.22	571.68
15	68.63	573.47
16	70.92	575.41
17	73.08	577.49
18	75.09	579.71
19	76.97	582.06
20	78.68	584.52
21	80.24	587.08
22	81.62	589.74
23	82.50	591.73

*** 1.859 ***

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Failure Surface Specified By 24 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	24.00	564.70
2	26.82	563.68
3	29.71	562.88
4	32.66	562.29
5	35.63	561.93
6	38.63	561.79
7	41.63	561.87
8	44.61	562.18
9	47.57	562.71
10	50.47	563.46
11	53.31	564.42
12	56.07	565.60
13	58.74	566.97
14	61.30	568.54
15	63.73	570.30
16	66.02	572.23
17	68.16	574.33
18	70.14	576.59
19	71.95	578.98
20	73.57	581.51
21	75.00	584.14
22	76.23	586.88
23	77.25	589.70
24	77.73	591.42

*** 1.865 ***

result.out

Failure Surface Specified By 26 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	26.00	564.70
2	28.79	563.60
3	31.65	562.70
4	34.57	562.00
5	37.53	561.50
6	40.52	561.21
7	43.51	561.13
8	46.51	561.26
9	49.49	561.60
10	52.44	562.15
11	55.35	562.90
12	58.19	563.84
13	60.97	564.99
14	63.65	566.33
15	66.24	567.84
16	68.71	569.54
17	71.06	571.40
18	73.28	573.43
19	75.35	575.60
20	77.26	577.91
21	79.01	580.35
22	80.58	582.91
23	81.97	585.56
24	83.17	588.31
25	84.18	591.14
26	84.38	591.86

*** 1.872 ***

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Failure Surface Specified By 26 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	24.00	564.70
2	26.82	563.67
3	29.70	562.83
4	32.63	562.17
5	35.59	561.72
6	38.58	561.45
7	41.58	561.39
8	44.58	561.52
9	47.56	561.85
10	50.51	562.37
11	53.42	563.09
12	56.28	564.00
13	59.08	565.09
14	61.79	566.36
15	64.42	567.81
16	66.95	569.43
17	69.36	571.21
18	71.65	573.15
19	73.81	575.23
20	75.83	577.45
21	77.70	579.80
22	79.41	582.26
23	80.95	584.84
24	82.32	587.50
25	83.51	590.26
26	84.08	591.84

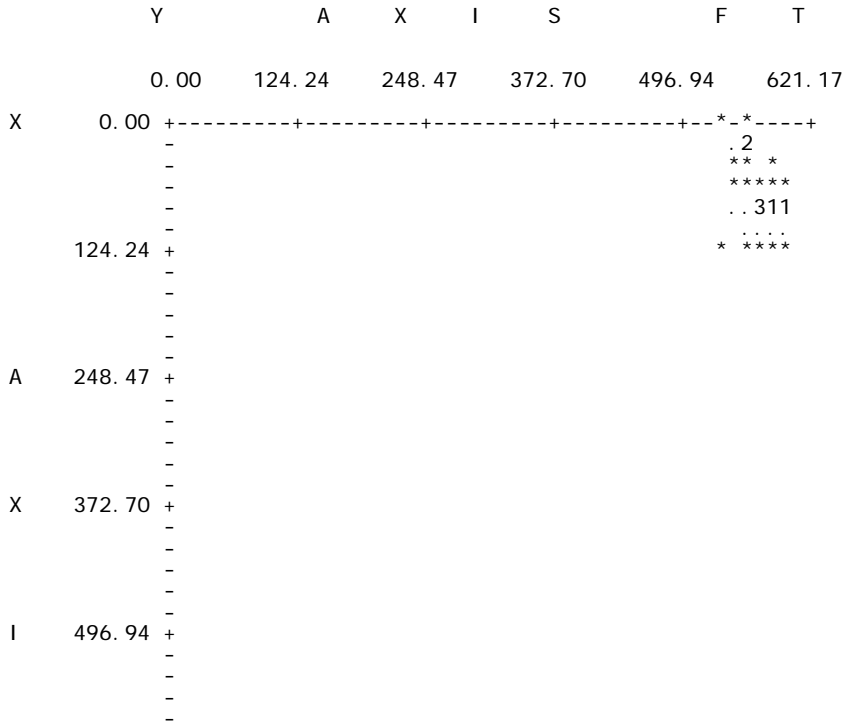
*** 1.874 ***

Failure Surface Specified By 28 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	21.00	564.70
2	23.63	563.26
3	26.36	562.02
4	29.18	560.98
5	32.06	560.15
6	34.99	559.53
7	37.97	559.13
8	40.96	558.94
9	43.96	558.98
10	46.95	559.24
11	49.91	559.71
12	52.83	560.40
13	55.69	561.30
14	58.48	562.41
15	61.18	563.72
16	63.78	565.23
17	66.26	566.92
18	68.60	568.78
19	70.81	570.82
20	72.86	573.01
21	74.74	575.34
22	76.45	577.81
23	77.98	580.39
24	79.31	583.08
25	80.44	585.86
26	81.36	588.71
27	82.07	591.63
28	82.09	591.71

*** 1.878 ***

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F	869.64	+
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T	993.87	+