

**Resource International, Inc.**

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

**DRAFT STRUCTURE  
FOUNDATION EXPLORATION  
REPORT**

*Prepared For:*  
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*Prepared By:*  
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**Rii Project No. B-10-020**

**August, 2013**





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May 31, 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 S  
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 S as part of the HAM-75-7.85 project. The proposed wall will be located south of the proposed Towne Street 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.**

Brian R. Trenner, P.E.  
Project Engineer

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 S 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 S. The total wall length is approximately 200 lineal feet.

### Exploration and Findings

Between November 18, 2011, and January 23, 2012, a total of two (2) structural borings, designated as B-012-0-11 and B-014-0-11, were drilled to a completion depth of 29.0 and 15.0 feet below the ground surface, respectively, at the locations illustrated on the boring plan presented in Appendix II of the full report.

Boring B-012 was drilled in the painted section between the exit ramp and drive lane of I-75 and encountered 6.0 inches of asphalt overlying 12.0 inches of aggregate base material at the ground surface. Boring B-014 was drilled in the right shoulder of the exit ramp from I-75 northbound to Towne Street and encountered 12.0 inches of gravel at the ground surface.

Underlying the surface materials, natural soils were encountered consisting of both granular soils and cohesive soils. The granular soils were generally described as brown and gray gravel and sand, gravel with sand and silt and coarse and fine sand (ODOT A-1-b, A-2-4, A-3a). The cohesive soils were generally described as brown and gray sandy silt and silt and clay (ODOT A-4a, A-6a) 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. The backslope behind the wall will be regraded, where necessary, to a maximum backslope of 3:1 (H:V).

Based upon proposed plan and cross section information provided by the Rii design team, wall heights along the alignment are anticipated to range from 6.0 to 11.0 feet. Based on the subsurface conditions encountered and the proposed geometry of the slope behind the wall, steel H-Piles 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 <sup>1</sup> (ft msl)			Shaft Spacing (ft)	Shaft Diameter (in)	Embedment Depth <sup>2</sup> (ft)	Pile Section
	Top	Ground	Tip				
H ≤ 9.0	552.0	543.0	531.0	8.0	24	12.0	HP 12x53
H > 9.0	552.0	541.0	526.0	8.0	24	15.0	HP 12x53

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  $q_n = 36.0$  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  $q_s = 1,000$  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 height 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 2.92 was determined for the maximum wall height at Station 446+00, 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, several new retaining walls 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 S 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 S. The total wall length is approximately 200 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 S is located along the east side of I-75, approximately 550 feet south of the Towne Street interchange with I-75. Overall, the project is located approximately 2.0 miles south of the Lockland split. The proposed wall begins at Station 445+40 and continues north to Station 447+40 along the east side of I-75. The wall will be located along the east side of I-75 and will be constructed along the slope between the existing exit ramp from I-75 northbound to Towne Street and the STAR64 WSTR-TV Cincinnati station located at 5177 Fishwick Drive, Cincinnati, Ohio. The existing I-75 roadway that runs adjacent to the proposed structure is currently a six-lane, asphalt paved road with an additional lane for the exit ramp for I-75 northbound to Towne Street. The existing STAR64 WSTR-TV Cincinnati station sits back off of Fishwick Drive and there is a satellite array south of the building. The terrain east of I-75 is elevated from the existing roadway and the I-75 mainline slopes downward from the I-75 bridge structure over Towne Street to the south.

## 3.0 EXPLORATION

Between November 18, 2011, and January 23, 2012, a total of two (2) structural borings, designated as B-012-0-11 and B-014-0-11, were drilled to a completion depth of 29.0 and 15.0 feet below the ground surface, respectively, at the locations illustrated on the boring plan presented in Appendix II. Boring B-012 was originally planned to be located in the shoulder of I-75 northbound approximately 40 feet south of the final location that the boring was performed at. Several attempts were conducted at the original location and at offset locations nearby; however, the borings were terminated after encountering auger refusal at depths less than 5.0 feet below the ground surface. Auger refusal is defined as no or insignificant observable advancement of the augers with the weight of the drill rig driving the augers. To avoid closing the exit ramp to perform the boring in the lane, the boring was relocated in the painted section between the exit ramp and drive lane of I-75.



**Table 1. Test Boring Summary**

Boring Number	Station	Offset	Latitude	Longitude	Ground Elevation (feet)	Boring Depth
B-012-0-11	447+36.53	57.0' Rt.	39.182443491 °N	84.484274455 °W	547.6	29.0
B-014-0-11	448+23.81	96.7' Rt.	39.182628250 °N	84.484029060 °W	548.2	15.0

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 4.5-inch outer diameter, continuous solid flight auger to advance the holes. Standard penetration testing (SPT) and split spoon sampling were performed in boring B-012 at 2.5-foot increments of depth to the boring termination depth, and continuously to a depth of 10.5 feet and at 5.0-foot increments thereafter to the boring termination depth in boring B-014. 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	16
Plastic and Liquid Limits	AASHTO T89, T90	5
Sieve/Hydrometers	AASHTO T88	5

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 on the boring logs in Appendix IV. 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**

Boring B-012 was drilled in the painted section between the exit ramp and drive lane of I-75 and encountered 6.0 inches of asphalt overlying 12.0 inches of aggregate base material at the ground surface. Boring B-014 was drilled in the right shoulder of the exit ramp from I-75 northbound to Towne Street and encountered 12.0 inches of gravel at the ground surface.

##### **4.2 Subsurface Soils**

Underlying the surface materials, natural soils were encountered consisting of both granular soils and cohesive soils. The granular soils were generally described as brown and gray gravel and sand, gravel with sand and silt and coarse and fine sand (ODOT



A-1-b, A-2-4, A-3a). The cohesive soils were generally described as brown and gray sandy silt and silt and clay (ODOT A-4a, A-6a) 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 loose ( $5 \leq N_{60} \leq 10$  blows per foot [bpf]) to very dense ( $N_{60} > 50$  bpf). Overall blow counts recorded from the SPT sampling ranged from 8 bpf to split spoon sampler refusal, generally increasing with depth. Split spoon sampler refusal is defined as exceeding 50 blows with less than 6 inches of penetration by the split spoon sampler. The shear strength and consistency of the cohesive soils are primarily derived from the hand penetrometer values (HP). The cohesive soil encountered ranged from very stiff ( $2.0 < HP \leq 4.0$  tsf) to hard ( $HP > 4.0$  tsf). The unconfined compressive strength of the cohesive soil samples tested, obtained from the hand penetrometer, ranged from 4.0 tsf to over 4.5 tsf (limit of the instrument).

Natural moisture contents of the soil samples tested ranged from 3 to 18 percent. The natural moisture contents of the cohesive soil samples tested for plasticity index ranged from 1 to 4 percent below their corresponding plastic limits. The moisture contents of the native soils are generally considered to be slightly to moderately below their corresponding 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 either 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 the existing slope will have to be cut and the retaining wall constructed to avoid regrading the slope which would require the relocation of the STAR64 WSTR-TV Cincinnati station satellite array that is situated behind the existing building. The backslope behind the wall will be regraded, where necessary, to a maximum backslope of 3:1 (H:V).

### 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 from 6.0 to 11.0 feet. Based on the subsurface conditions encountered and the proposed geometry of the slope behind the wall, steel H-Piles 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 <sup>1</sup> (ft msl)			Shaft Spacing (ft)	Shaft Diameter (in)	Embedment Depth <sup>2</sup> (ft)	Pile Section
	Top	Ground	Tip				
H ≤ 9.0	552.0	543.0	531.0	8.0	24	12.0	HP 12x53
H > 9.0	552.0	541.0	526.0	8.0	24	15.0	HP 12x53

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 elevation listed in Table 3 coincides with the bottom of wall elevation, and the embedment depth reflects exclusively the length of the shaft in contact with the soil. The wall was evaluated to determine the center to center spacing required between the drilled shaft elements as well as the required embedment depth based on the maximum exposed wall height along the alignment. Provided drilled shafts are proportioned as outlined above, a nominal end bearing resistance of  $q_n = 36.0$  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  $q_s = 1,000$  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.

It should be noted that a boring was not obtained at the top of the slope behind the proposed wall alignment as the final proposed alignment was not known at the time of the execution of the field work. Therefore, the soil parameters for the retained soil behind the wall were assumed, and a friction angle of  $\phi = 29$  degrees was utilized in determining the lateral earth pressure behind the wall. **It is recommended that a confirmation boring be conducted at the top of the slope behind the proposed wall alignment to verify the soil conditions of the retained soil as well as the subsurface soils that the shafts will be embedded in, and also to verify that no deleterious soils or unfavorable soil conditions exist near the location of the wall.**

### 5.1.1 Lateral Design

The foundation elements for the soldier pile and lagging retaining wall 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)	$\epsilon_{50}$ (soil)
B-012-0-11	0-11.0	4	130 pcf	$\phi = 34^\circ$	225 pci	N/A
	11.0-20.5	3	125 pcf	$C_u = 4,000$ psf	2000 pci	0.004
	Below 20.5	4	135 pcf	$\phi = 35^\circ$	225 pci	N/A

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 maximum exposed wall height along the alignment. 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 check the global stability of the soldier pile and lagging retaining wall system. Global stability was checked at the location of the maximum wall height of 9.5 feet, at Station 446+00. Soil parameters utilized in external stability analysis 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:

1. Retained Soil (Assumed Soil Conditions)
  - §  $\phi = 29^\circ$
  - §  $\gamma = 120$  pcf
2. Bearing Soil (Dense to Very Dense Natural Granular Soil)
  - §  $\phi = 34^\circ$  to  $35^\circ$
  - §  $\gamma = 130$  pcf to  $135$  pcf



### 3. Bearing Soil (Very Stiff to Hard Natural Cohesive Soil)

$$\S \phi = 27^\circ$$

$$\S c = 237.4 \text{ psf}$$

$$\S \gamma = 125 \text{ pcf}$$

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.

$$\S \phi = 40^\circ$$

$$\S c = 10,000 \text{ psf}$$

$$\S \gamma = 140 \text{ pcf}$$

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 sections analyzed, a resulting factor of safety of 2.92 was determined for the maximum wall height at Station 446+00, 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 V.

## 5.2 Lateral Earth Pressure

For the soil types encountered in the borings, the “in-situ” unit weight ( $\gamma$ ), cohesion ( $c$ ), effective angle of friction ( $\phi'$ ), 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 6 and Table 7.



**Table 6. Estimated Undrained (Short-term) Soil Parameters for Design**

Soil Type	$\gamma$ (pcf) <sup>1</sup>	$c$ (psf)	$\phi$	$k_a$ <sup>2</sup>	$k_o$	$k_p$ <sup>2</sup>
Very Stiff to Hard Cohesive Soil	120	4,000	0°	1.0	1.0	1.0
Loose to Medium Dense Granular Soil	125	0	29°	0.34 / 0.42	0.52	2.88 / 2.15
Dense to Very Dense Granular Soil	135	0	34°	0.28 / 0.33	0.44	3.54 / 2.74
Compacted Cohesive Engineered Fill	125	1,500	0°	1.0	1.0	1.0
Compacted Granular Engineered Fill	135	0	33°	0.30 / 0.34	0.46	3.39 / 2.61

1. When below groundwater table, use effective unit weight,  $\gamma' = \gamma - 62.4$  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 3:1 (H:V).

**Table 7. Estimated Drained (Long-term) Soil Parameters for Design**

Soil Type	$\gamma$ (pcf) <sup>1</sup>	$c$ (psf)	$\phi$	$k_a$ <sup>2</sup>	$k_o$	$k_p$ <sup>2</sup>
Natural Cohesive Soil	120	0	26°	0.39 / 0.49	0.56	2.56 / 1.84
Loose to Medium Dense Granular Soil	125	0	29°	0.34 / 0.42	0.52	2.88 / 2.15
Dense to Very Dense Granular Soil	135	0	34°	0.28 / 0.33	0.44	3.54 / 2.74
Compacted Cohesive Engineered Fill	125	0	28°	0.36 / 0.44	0.53	2.77 / 2.04
Compacted Granular Engineered Fill	135	0	33°	0.30 / 0.34	0.46	3.39 / 2.61

1. When below groundwater table, use effective unit weight,  $\gamma' = \gamma - 62.4$  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 3:1 (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 3:1 (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 8. Excavation Back Slopes**

<b>Soil</b>	<b>Maximum Back Slope</b>	<b>Notes</b>
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.

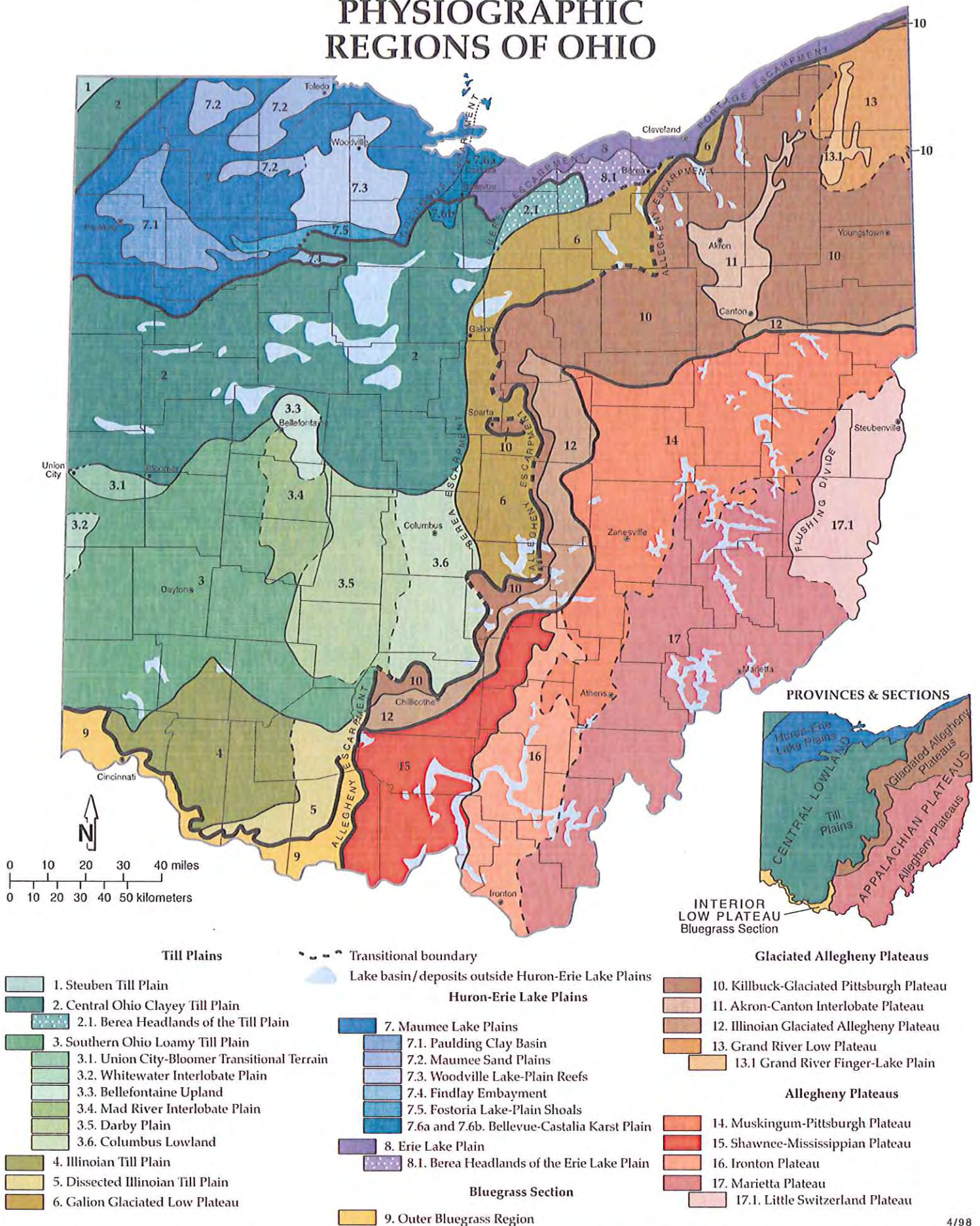
The scope of our services does not include any environmental assessment or investigation for the presence or absence of hazardous or toxic materials in the soil, groundwater, or surface water within or beyond the site studied. Any statements in this report or on the test boring logs regarding odors,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

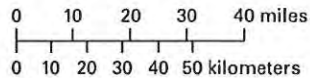
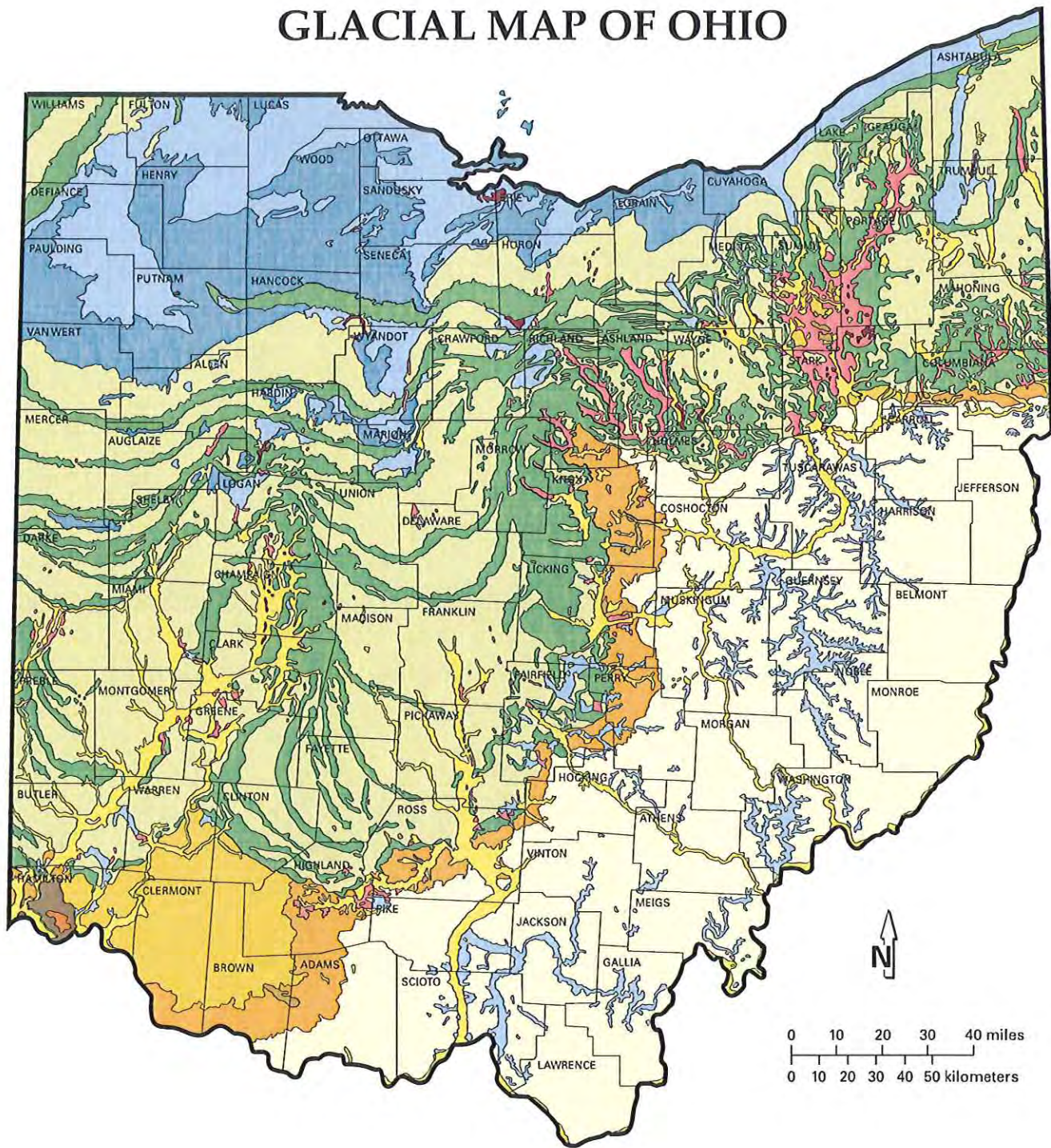















**APPENDIX I**  
**STATE GEOLOGY**

# PHYSIOGRAPHIC REGIONS OF OHIO



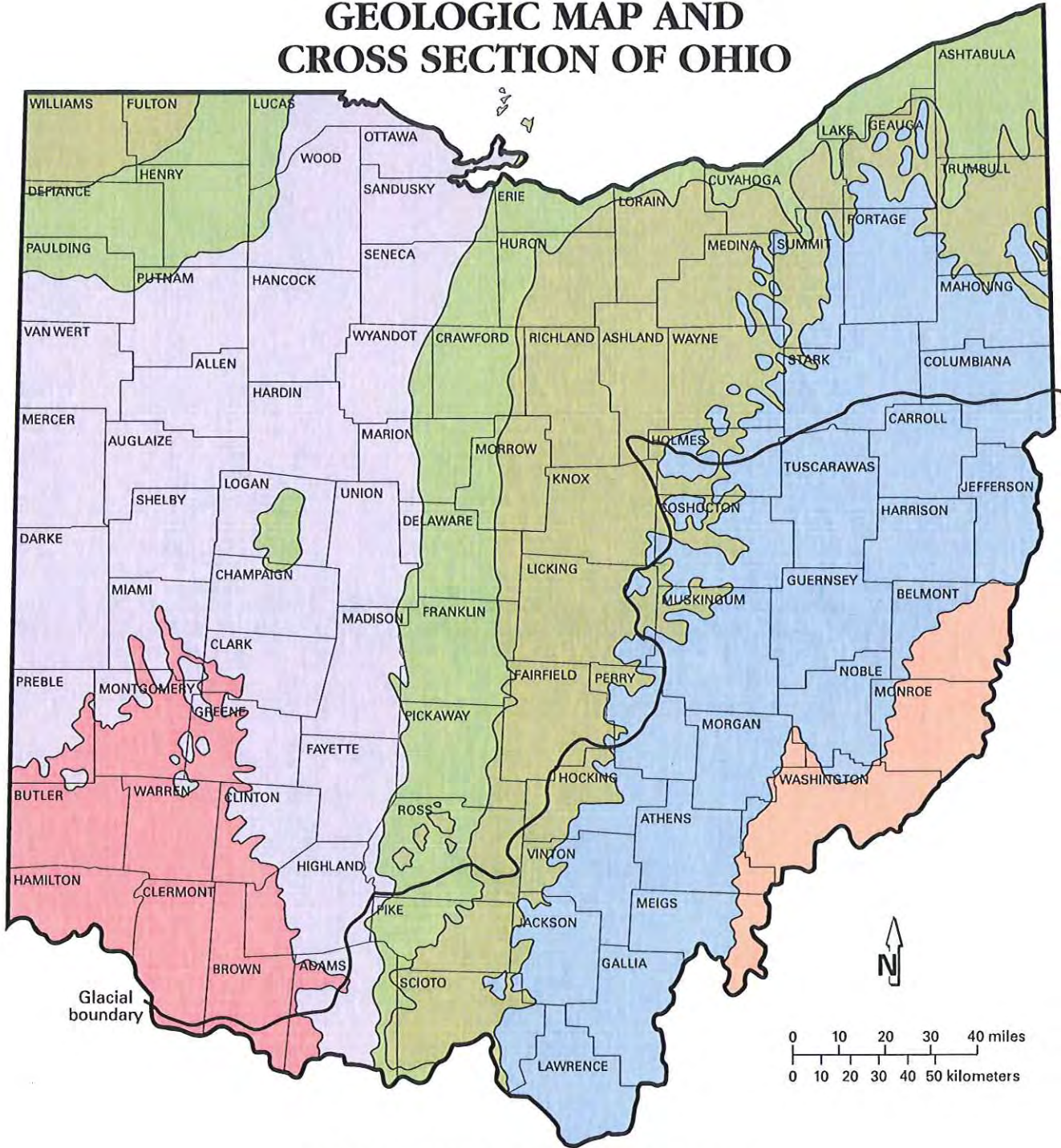
# GLACIAL MAP OF OHIO









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

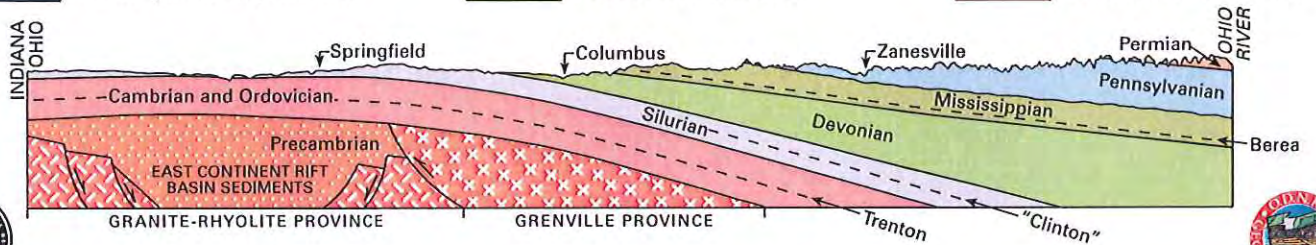


# GEOLOGIC MAP AND CROSS SECTION OF OHIO



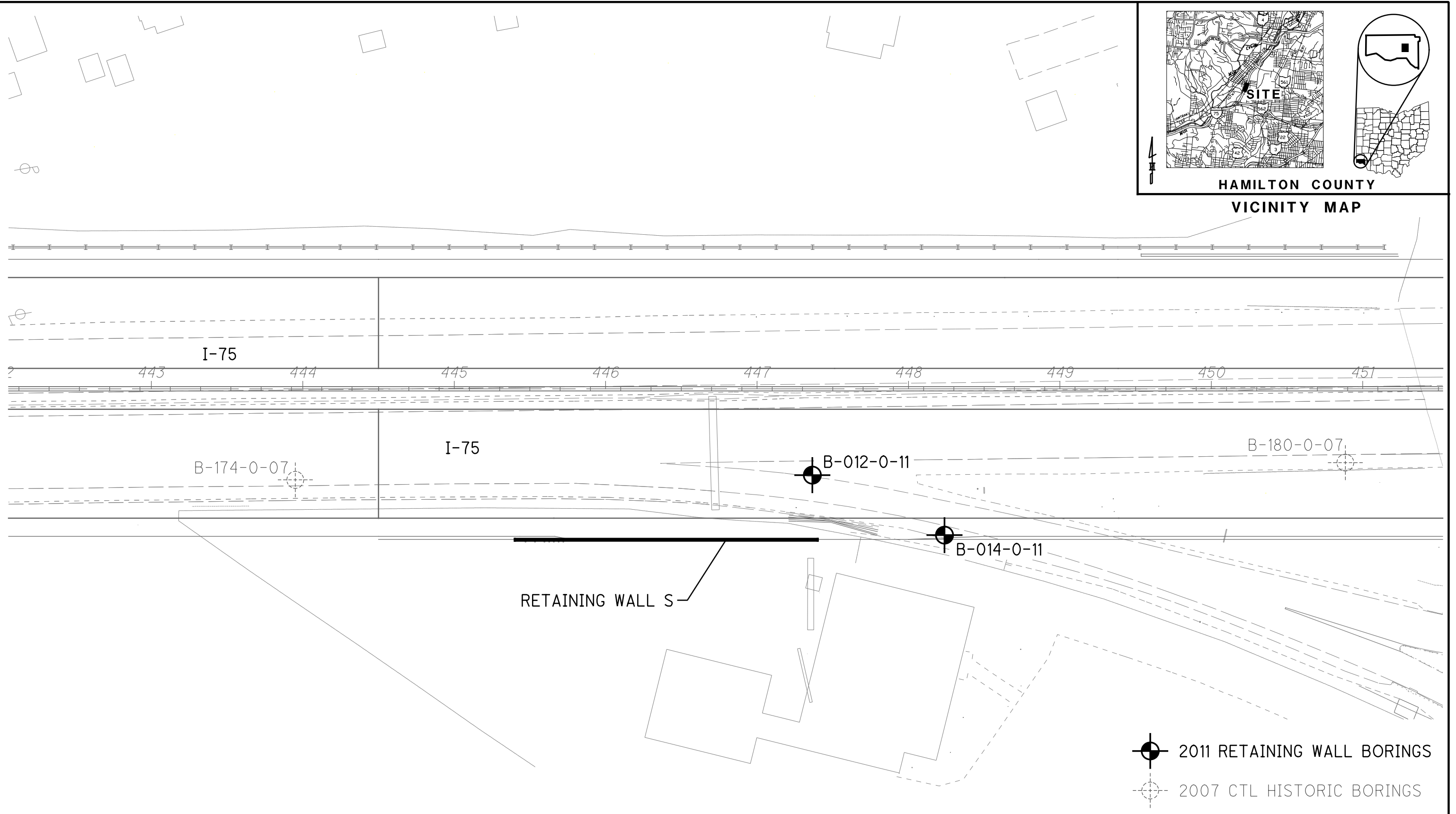
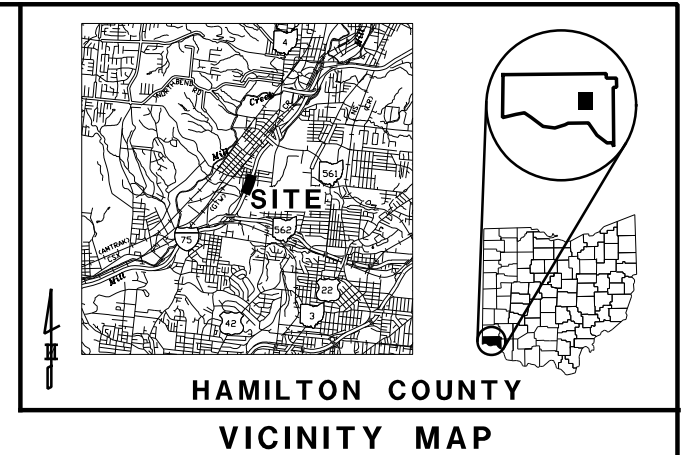
GEOLOGIC SYSTEM (million years before present)

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



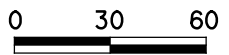
**APPENDIX II**

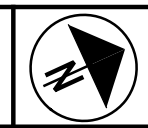
**VICINITY MAP AND BORING PLAN**



 2011 RETAINING WALL BORINGS  
 2007 CTL HISTORIC BORINGS

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

PROJECT NO.  
 Rii B-10-020  
 SCALE: 1"=60'  




DRAWN  
 RRM  
 REVIEWED  
 BRT  
 DATE  
 5-31-12



**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 (N<sub>60</sub>)</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 (N<sub>60</sub>)</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 <sub>0</sub> /LL <sub>L</sub> 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	Uncontrolled Fill (Describe)	Bouldery Zone	Peat, S-Sedimentary, W-Woody, F-Fibrous, L-Loamy & etc
Pavement or Base			

\* 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 <sup>-</sup>	=	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 <sup>4-</sup>	=	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 <sub>60</sub> 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 - 5/18/12 14:58 - C:\GINT8\PROJECTS\2010\B-10-020\B-12 B-14 RET WALLS.GPJ

PID: 77889 BR ID: NA PROJECT: HAM-75-7.85 STATION / OFFSET: 447+36.53 / 57.0' Rt START: 1/23/12 END: 1/23/12 PG 2 OF 2 B-012-0-11

MATERIAL DESCRIPTION AND NOTES	ELEV.	DEPTHS	SPT/ RQD	N <sub>60</sub>	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%)					ATTERBERG			WC	ODOT CLASS (GI)	BACK FILL
								GR	CS	FS	SI	CL	LL	PL	PI			
	519.6																	
	518.6	EOB	11	29	67	SS-10	-	-	-	-	-	-	-	-	-	7	A-3a (V)	< < < < > > > >

[Empty Boring Log Area]

NOTES: GROUNDWATER NOT ENCOUNTERED DURING DRILLING; CAVE-IN DEPTH @ 17.4'  
 ABANDONMENT METHODS, MATERIALS, QUANTITIES: COMPACTED WITH THE AUGER 100 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: 448+23.81 / 96.7' Rt	<b>EXPLORATION ID</b> <b>B-014-0-11</b>
	TYPE: RETAINING WALL	SAMPLING FIRM / LOGGER: RII / A.D.	HAMMER: CME AUTOMATIC	ALIGNMENT: PROPOSED CL I-75	
	PID: 77889 BR ID: NA	DRILLING METHOD: 4.5" SFA	CALIBRATION DATE: 5/6/11	ELEVATION: 548.2 (MSL) EOB: 15.0 ft.	PAGE
	START: 11/18/11 END: 11/18/11	SAMPLING METHOD: SPT	ENERGY RATIO (%): 77.1	COORD: 39.182628250, 84.484029060	1 OF 1

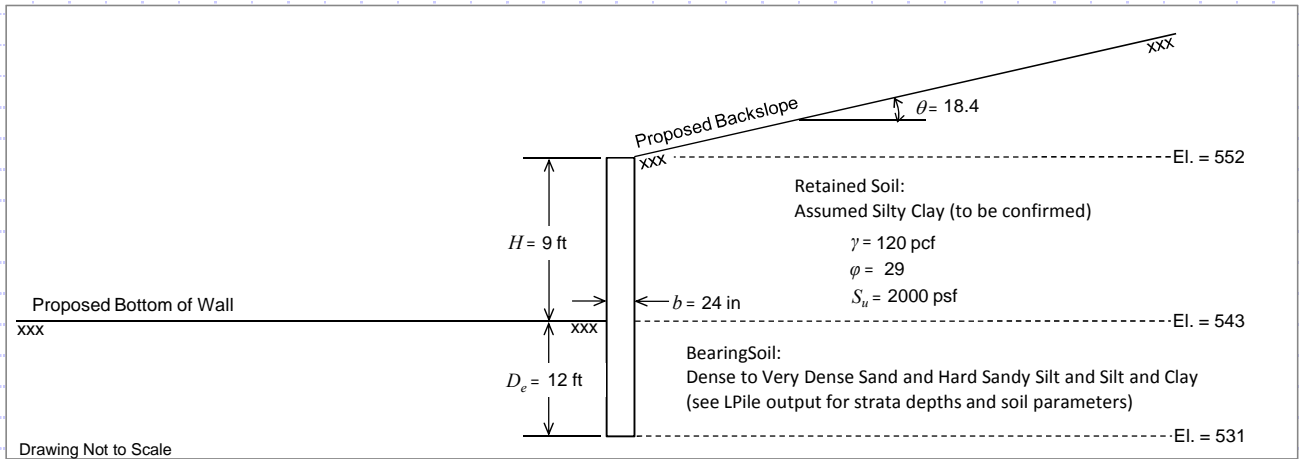
MATERIAL DESCRIPTION AND NOTES	ELEV.	DEPTHS	SPT/RQD	N <sub>60</sub>	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%)					ATTERBERG			WC	ODOT CLASS (GI)	BACK FILL	
								GR	CS	FS	SI	CL	LL	PL	PI				
1.0' - GRAVEL (12.0")	548.2																		
LOOSE, BROWN <b>COARSE AND FINE SAND</b> , TRACE CLAY, TRACE SILT, TRACE FINE GRAVEL, MOIST TO WET.	547.2	1	7	19	72	SS-1	-	-	-	-	-	-	-	-	10	A-3a (V)	<V>		
		2	8															<V>	
		3																	<V>
		4	6	14	72	SS-2	-	2	13	67	8	10	NP	NP	NP	14	A-3a (0)	<V>	
		5	4																<V>
		6	5	14	67	SS-3	-	-	-	-	-	-	-	-	-	18	A-3a (V)	<V>	
		7	6																<V>
HARD, BROWN <b>SILT AND CLAY</b> , SOME COARSE TO FINE SAND, DAMP.	539.7	8																<V>	
		9	5	30	61	SS-4	4.5+	0	12	23	35	30	26	15	11	13	A-6a (6)	<V>	
		10	10	13															<V>
VERY DENSE, BROWN <b>GRAVEL WITH SAND AND SILT</b> , MOIST.	537.2	11	12	57	67	SS-5	-	-	-	-	-	-	-	-	18	A-2-4 (V)	<V>		
		12	14	30															<V>
DENSE, BROWN <b>GRAVEL AND SAND</b> , TRACE SILT, MOIST.	535.2	13																<V>	
		14	9	39	56	SS-6	-	-	-	-	-	-	-	-	8	A-1-b (V)	<V>		
	533.2	15	12	18														<V>	
EOB																			

2010 STD. ODOT BORING LOG (8.5 X 11)-RII - OH DOT.GDT - 5/31/12 07:41 - G:\GINT8\PROJECTS\2010\B-10-020\B-10-020 B-12 B-14 RET WALLS.GPJ

NOTES: GROUNDWATER NOT ENCOUNTERED DURING DRILLING  
 ABANDONMENT METHODS, MATERIALS, QUANTITIES: COMPACTED WITH THE AUGER 100 LBS BENTONITE CHIPS AND SOIL CUTTINGS

**APPENDIX V**

**PILE AND LAGGING RETAINING WALL  
CALCULATIONS**



**Retaining Wall and Soil Parameters**

Retaining Wall Height, (H) =	9.0 ft
Soil Friction Angle, ( $\phi'$ ) =	29°
Soil Total Unit Weight, ( $\gamma$ ) =	120 pcf
Soil Undrained Shear Strength, ( $s_u$ ) =	2000 psf
Backslope Angle, ( $\theta$ ) =	18.4°
Embedment Depth, ( $D_e$ ) =	12 ft
Shaft Spacing, (S) =	8.0 ft O.C.
Shaft Diameter, (b) =	24 in

**Rankine Earth Pressures**

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

$$K_a = 0.4189$$

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

$$K_p = 2.1483$$

**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**

$S/b = 4.00$   
 $\beta_a = 1.0000$

**Structural Element Properties**

Section Type: **HP 12x53**

E = 29,000 ksi	d = 11.8 in	$I_x = 393 \text{ in}^4$	$Z_x = 74 \text{ in}^3$
$A_s = 15.5 \text{ in}^2$	$t_w = 0.435 \text{ in}$	$I_x = 49.1 \text{ in}^4 \text{ per ft}$	$Z_x = 9.3 \text{ in}^3 \text{ per ft}$
$f_y = 50 \text{ ksi}$	$t_f = 0.435 \text{ in}$	$r_s = 5.03 \text{ in}$	T = 9.5 in
			S = 66.8 in <sup>3</sup>

**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.

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

$$P_{EH} = (120 \text{ pcf})(9.0 \text{ ft})(8 \text{ ft O.C.})(0.419)(1.00) \quad \text{(Service I)}$$

$$P_{EH} = (120 \text{ pcf})(9.0 \text{ ft})(8 \text{ ft O.C.})(0.419)(1.50) \quad \text{(Strength I)}$$

$$P_{EH} = 3619.6 \text{ lb/ft} \quad \text{(Service I)}$$

$$P_{EH} = 5429.3 \text{ lb/ft} \quad \text{(Strength I)}$$

**Check Deflection - (Loading Case - Service I)**

$$\left(\frac{\delta_h}{H}\right) \cdot 100\% < 1.0\% \quad \longrightarrow \quad \delta_h = 0.632 \text{ in (Determined from LPILE)} \quad \longrightarrow \quad 0.59\% < 1.0\% \quad \text{OK}$$

**Capacity Verification - (Loading Case - Strength I)**

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

Maximum Bending Moment,  $M_u = 148.8$  kip-ft per section (Determined from LPILE analysis)

Maximum Shear Force,  $V_u = 30.3$  kip per section (Determined from LPILE analysis)

Factored Flexural Resistance,  $\phi_f M_n = 308.3$  kip-ft per section  $\longrightarrow M_u < \phi_f M_n \longrightarrow 148.8 \text{ kip-ft} < 308.3 \text{ kip-ft}$  **OK**

Factored Shear Resistance,  $\phi_v V_n = 148.6$  kip per section  $\longrightarrow V_u < \phi_v V_n \longrightarrow 30.3 \text{ kip} < 148.6 \text{ kip}$  **OK**

$$S_{Req} = M_u \times \left(\frac{12}{50 \text{ ksi}}\right) = (148.8 \text{ kip-ft})(12 \text{ in}) / (50 \text{ ksi}) = 35.7 \text{ in}^3 \quad \longrightarrow \quad S_{Req} < S_{Section} \quad \longrightarrow \quad 35.7 \text{ in}^3 < 66.8 \text{ in}^3 \quad \text{OK}$$

Retaining Wall S - Pile and Lagging - 9.0 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

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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 S\Revised Analysis - 8-8-13\9 ft Wall Ht\  
Name of input data file: Retaining Wall S - Pile and Lagging - 9.0 ft Wall Ht.lpd  
Name of output file: Retaining Wall S - Pile and Lagging - 9.0 ft Wall Ht.lpo  
Name of plot output file: Retaining Wall S - Pile and Lagging - 9.0 ft Wall Ht.lpp  
Name of runtime file: Retaining Wall S - Pile and Lagging - 9.0 ft Wall Ht.lpr

Time and Date of Analysis

Date: August 9, 2013 Time: 10:16:09

Problem Title

HAM-75-7.85 - Retaining Wall S - Pile and Lagging - 9 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 = 324.00 in

Retaining Wall S - Pile and Lagging - 9.0 ft Wall Ht. I po

Depth of ground surface below top of pile = 108.00 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	11.80000000	393.0000	15.5000	29000000.
2	108.0000	11.80000000	393.0000	15.5000	29000000.
3	108.0000	24.00000000	16286.0000	452.4000	3122019.
4	324.0000	24.00000000	16286.0000	452.4000	3122019.

-----  
Soil and Rock Layering Information  
-----

The soil profile is modelled using 3 layers

Layer 1 is sand, p-y criteria by Reese et al., 1974

Distance from top of pile to top of layer = 108.000 in  
 Distance from top of pile to bottom of layer = 246.000 in  
 p-y subgrade modulus k for top of soil layer = 225.000 lbs/in\*\*3  
 p-y subgrade modulus k for bottom of layer = 225.000 lbs/in\*\*3

Layer 2 is stiff clay without free water

Distance from top of pile to top of layer = 246.000 in  
 Distance from top of pile to bottom of layer = 360.000 in

Layer 3 is sand, p-y criteria by Reese et al., 1974

Distance from top of pile to top of layer = 360.000 in  
 Distance from top of pile to bottom of layer = 390.000 in  
 p-y subgrade modulus k for top of soil layer = 225.000 lbs/in\*\*3  
 p-y subgrade modulus k for bottom of layer = 225.000 lbs/in\*\*3

(Depth of lowest layer extends 66.00 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	108.00	.07500
2	246.00	.07500
3	246.00	.07200
4	360.00	.07200
5	360.00	.07800
6	390.00	.07800

-----  
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 <sub>rm</sub>	RQD %
1	108.000	.00000	34.00	-----	-----
2	246.000	.00000	34.00	-----	-----
3	246.000	27.80000	.00	.00500	.0
4	360.000	27.80000	.00	.00500	.0
5	360.000	.00000	35.00	-----	-----
6	390.000	.00000	35.00	-----	-----

Notes:

Retaining Wall S - Pile and Lagging - 9.0 ft Wall Ht.lpo

- (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<sub>rm</sub> 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	108.000	1.0000	1.0000
2	390.000	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	108.000	301.60000

-----  
 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	.551985	-1.5669E-06	1.8601E-08	-.0038899	2.3524E-08	0.0000	0.0000
3.240	.539381	5.9364	16.4900	-.0038899	.0891214	0.0000	0.0000

Retaining Wall S - Pile and Lagging - 9.0 ft Wall Ht. Ipo

6. 480	. 526778	106. 8551	60. 4633	- .0038899	1. 6042	0. 0000	0. 0000
9. 720	. 514175	397. 7383	133. 7521	- .0038898	5. 9711	0. 0000	0. 0000
12. 960	. 501572	973. 5684	236. 3564	- .0038896	14. 6159	0. 0000	0. 0000
16. 200	. 488970	1929. 3277	368. 2762	- .0038892	28. 9645	0. 0000	0. 0000
19. 440	. 476370	3359. 9983	529. 5116	- .0038885	50. 4427	0. 0000	0. 0000
22. 680	. 463773	5360. 5627	720. 0625	- .0038872	80. 4766	0. 0000	0. 0000
25. 920	. 451181	8026. 0031	939. 9289	- .0038853	120. 4922	0. 0000	0. 0000
29. 160	. 438596	11451. 3017	1189. 1108	- .0038826	171. 9152	0. 0000	0. 0000
32. 400	. 426022	15731. 4409	1467. 6082	- .0038787	236. 1718	0. 0000	0. 0000
35. 640	. 413462	20961. 4030	1775. 4212	- .0038735	314. 6877	0. 0000	0. 0000
38. 880	. 400922	27236. 1702	2112. 5497	- .0038666	408. 8891	0. 0000	0. 0000
42. 120	. 388406	34650. 7248	2478. 9937	- .0038578	520. 2017	0. 0000	0. 0000
45. 360	. 375923	43300. 0491	2874. 7532	- .0038467	650. 0516	0. 0000	0. 0000
48. 600	. 363479	53279. 1254	3299. 8282	- .0038330	799. 8647	0. 0000	0. 0000
51. 840	. 351085	64682. 9359	3754. 2188	- .0038162	971. 0670	0. 0000	0. 0000
55. 080	. 338750	77606. 4631	4237. 9249	- .0037960	1165. 0843	0. 0000	0. 0000
58. 320	. 326487	92144. 6890	4750. 9465	- .0037719	1383. 3427	0. 0000	0. 0000
61. 560	. 314308	108393.	5293. 2836	- .0037434	1627. 2680	0. 0000	0. 0000
64. 800	. 302230	126445.	5864. 9362	- .0037100	1898. 2862	0. 0000	0. 0000
68. 040	. 290267	146397.	6465. 9044	- .0036712	2197. 8233	0. 0000	0. 0000
71. 280	. 278440	168344.	7096. 1881	- .0036265	2527. 3052	0. 0000	0. 0000
74. 520	. 266768	192381.	7755. 7873	- .0035752	2888. 1578	0. 0000	0. 0000
77. 760	. 255273	218602.	8444. 7020	- .0035168	3281. 8071	0. 0000	0. 0000
81. 000	. 243979	247102.	9162. 9322	- .0034506	3709. 6791	0. 0000	0. 0000
84. 240	. 232913	277978.	9910. 4780	- .0033760	4173. 1995	0. 0000	0. 0000
87. 480	. 222103	311322.	10687. 3393	- .0032922	4673. 7946	0. 0000	0. 0000
90. 720	. 211579	347231.	11493. 5161	- .0031986	5212. 8900	0. 0000	0. 0000
93. 960	. 201376	385800.	12329. 0084	- .0030944	5791. 9119	0. 0000	0. 0000
97. 200	. 191528	427123.	13193. 8162	- .0029788	6412. 2861	0. 0000	0. 0000
100. 440	. 182073	471296.	14087. 9396	- .0028511	7075. 4385	0. 0000	0. 0000
103. 680	. 173052	518413.	15011. 3785	- .0027105	7782. 7952	0. 0000	0. 0000
106. 920	. 164509	568570.	15882. 4973	- .0025560	8535. 7821	0. 0000	0. 0000
110. 160	. 156490	621332.	16248. 6472	- .0024553	457. 8155	-22. 1732	459. 0797
113. 400	. 148599	673861.	16119. 3842	- .0024141	496. 5205	-57. 6187	1256. 3014
116. 640	. 140847	725786.	15872. 7516	- .0023695	534. 7799	-94. 6237	2176. 7006
119. 880	. 133244	776717.	15505. 5967	- .0023216	572. 3074	-132. 0151	3210. 1104
123. 120	. 125803	826262.	15015. 9227	- .0022705	608. 8138	-170. 2527	4384. 7991
126. 360	. 118531	874020.	14403. 5827	- .0022164	644. 0032	-207. 7350	5678. 3429
129. 600	. 111441	919597.	13672. 5150	- .0021592	677. 5859	-243. 5414	7080. 6740
132. 840	. 104540	962618.	12828. 9187	- .0020992	709. 2848	-277. 1971	8591. 1816
136. 080	. 097837	1002728.	11879. 4225	- .0020366	738. 8395	-308. 9116	10229. 9675
139. 320	. 091342	1039596.	10832. 7776	- .0019716	766. 0049	-337. 1655	11959. 5888
142. 560	. 085062	1072925.	9701. 2168	- .0019042	790. 5623	-361. 3289	13763. 0050
145. 800	. 079003	1102460.	8495. 2149	- .0018349	812. 3248	-383. 1167	15712. 0837
149. 040	. 073171	1127974.	7222. 8907	- .0017639	831. 1240	-402. 2685	17812. 2887
152. 280	. 067573	1149265.	5896. 1384	- .0016913	846. 8116	-416. 7144	19980. 7093
155. 520	. 062212	1166181.	4530. 8246	- .0016175	859. 2760	-426. 0719	22189. 9287
158. 760	. 057091	1178624.	3136. 0173	- .0015428	868. 4447	-434. 9202	24682. 2685
162. 000	. 052214	1186502.	1718. 7917	- .0014675	874. 2494	-439. 9104	27297. 3806
165. 240	. 047582	1189762.	293. 2055	- .0013918	876. 6514	-440. 0811	29966. 4214
168. 480	. 043196	1188402.	-1124. 9062	- .0013160	875. 6493	-435. 2965	32650. 6199
171. 720	. 039054	1182473.	-2519. 0426	- .0012405	871. 2803	-425. 2815	35281. 8701
174. 960	. 035157	1172079.	-3872. 1852	- .0011654	863. 6218	-409. 9917	37783. 6051
178. 200	. 031502	1157381.	-5167. 4684	- .0010912	852. 7920	-389. 5658	40066. 5867
181. 440	. 028086	1138594.	-6394. 8592	- .0010181	838. 9489	-368. 0829	42461. 5170
184. 680	. 024905	1115942.	-7553. 6616	- .0009462	822. 2588	-347. 2272	45171. 6497
187. 920	. 021955	1089646.	-8639. 0699	- .0008760	802. 8828	-322. 7779	47634. 2783
191. 160	. 019229	1059961.	-9640. 2659	- .0008075	781. 0102	-295. 2443	49746. 8786
194. 400	. 016722	1027177.	-10548. 2757	- .0007410	756. 8539	-265. 2556	51393. 7728
197. 640	. 014428	991608.	-11356. 3462	- .0006766	730. 6458	-233. 5533	52448. 5220
200. 880	. 012338	953588.	-12060. 2870	- .0006147	702. 6313	-200. 9781	52778. 5254
204. 120	. 010445	913458.	-12660. 0048	- .0005552	673. 0622	-169. 2181	52492. 4270
207. 360	. 008740	871551.	-13189. 0378	- .0004983	642. 1841	-157. 3455	58328. 1805
210. 600	. 007216	827993.	-13678. 0909	- .0004442	610. 0891	-144. 5391	64901. 5585
213. 840	. 005862	782917.	-14124. 3797	- .0003928	576. 8760	-130. 9478	72375. 8723
217. 080	. 004670	736467.	-14522. 1966	- .0003444	542. 6501	-114. 6181	79519. 3200
220. 320	. 003630	688813.	-14856. 5004	- .0002990	507. 5376	-91. 7422	81881. 2800
223. 560	. 002733	640196.	-15120. 2203	- .0002567	471. 7154	-71. 0478	84243. 2400
226. 800	. 001967	590834.	-15320. 4937	- .0002174	435. 3437	-52. 5777	86605. 2000
230. 040	. 001323	540920.	-15464. 5420	- .0001814	398. 5654	-36. 3410	88967. 1600
233. 280	. 000792	490624.	-15559. 5633	- .0001485	361. 5059	-22. 3141	91329. 1200
236. 520	. 000361	440094.	-15612. 6264	- .0001189	324. 2739	-10. 4409	93691. 0800
239. 760	2. 14E-05	389454.	-15630. 5672	-9. 2434E-05	286. 9611	-. 6336476	96053. 0400
243. 000	-. 000238	338808.	-15619. 8868	-6. 9231E-05	249. 6433	7. 2265	98415. 0000
246. 240	-. 000427	288237.	-15121. 8256	-4. 9252E-05	212. 3815	300. 2187	2276721.
249. 480	-. 000557	240818.	-14060. 0141	-3. 2396E-05	177. 4419	355. 2205	2066040.
252. 720	-. 000637	197128.	-12880. 5790	-1. 8442E-05	145. 2498	372. 8259	1895828.
255. 960	-. 000677	157352.	-11654. 5164	-7. 1479E-06	115. 9416	384. 0029	1838942.
259. 200	-. 000683	121607.	-10399. 7722	1. 7402E-06	89. 6035	390. 5305	1851280.

Retaining Wall S - Pile and Lagging - 9.0 ft Wall Ht. I po								
262.440	- .000665	89961.5026	-9129.7805	8.4810E-06	66.2863	393.4149	1915948.	
265.680	- .000629	62445.9701	-7855.3139	1.3337E-05	46.0120	393.2928	2027391.	
268.920	- .000579	39059.0686	-6585.4059	1.6571E-05	28.7799	390.6009	2186244.	
272.160	- .000521	19772.5395	-5327.8697	1.8445E-05	14.5690	385.6560	2397649.	
275.400	- .000459	4534.4727	-4109.4641	1.9220E-05	3.3411	366.4463	2584757.	
278.640	- .000397	-6856.7879	-2996.4777	1.9146E-05	5.0523	320.5824	2618974.	
281.880	- .000335	-14882.7031	-2032.3594	1.8453E-05	10.9660	274.5524	2653190.	
285.120	- .000277	-20026.4770	-1215.3479	1.7341E-05	14.7561	229.7757	2687404.	
288.360	- .000223	-22758.1574	-539.7794	1.5978E-05	16.7689	187.2418	2721617.	
291.600	- .000173	-23524.2478	2.6020	1.4503E-05	17.3334	147.5615	2755829.	
294.840	- .000129	-22741.2962	421.5039	1.3029E-05	16.7565	111.0199	2790040.	
298.080	-8.91E-05	-20792.9023	727.1165	1.1642E-05	15.3208	77.6299	2824249.	
301.320	-5.35E-05	-18029.5811	929.3173	1.0405E-05	13.2847	47.1854	2858458.	
304.560	-2.16E-05	-14770.9263	1037.0449	9.3601E-06	10.8836	19.3131	2892665.	
307.800	7.17E-06	-11309.5304	1057.8395	8.5291E-06	8.3332	-6.4769	2926872.	
311.040	3.36E-05	-7916.1261	997.5466	7.9166E-06	5.8328	-30.7410	2961078.	
314.280	5.85E-05	-4845.4285	860.1802	7.5100E-06	3.5703	-54.0530	2995282.	
317.520	8.23E-05	-2342.1582	647.9489	7.2810E-06	1.7258	-76.9540	3029486.	
320.760	.000106	-646.7198	361.4442	7.1857E-06	.4765220	-99.9008	3063690.	
324.000	.000129	0.0000	0.0000	7.1651E-06	0.0000	-123.2129	1548946.	

Output Veri fi cation:

Computed forces and moments are within speci fied convergence li mits.

Output Summary for Load Case No. 1:

Pile-head deflection	=	.55198474 in
Computed slope at pile head	=	-.00388991
Maximum bending moment	=	1189762. lbs-in
Maximum shear force	=	16248.64716 lbs
Depth of maximum bending moment	=	165.24000 in
Depth of maximum shear force	=	110.16000 in
Number of iterations	=	16
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	.5519847	1189762.	16248.6472

-----  
Pile-head Deflection vs. Pile Length  
-----

Boundary Condition Type 1, Shear and Moment

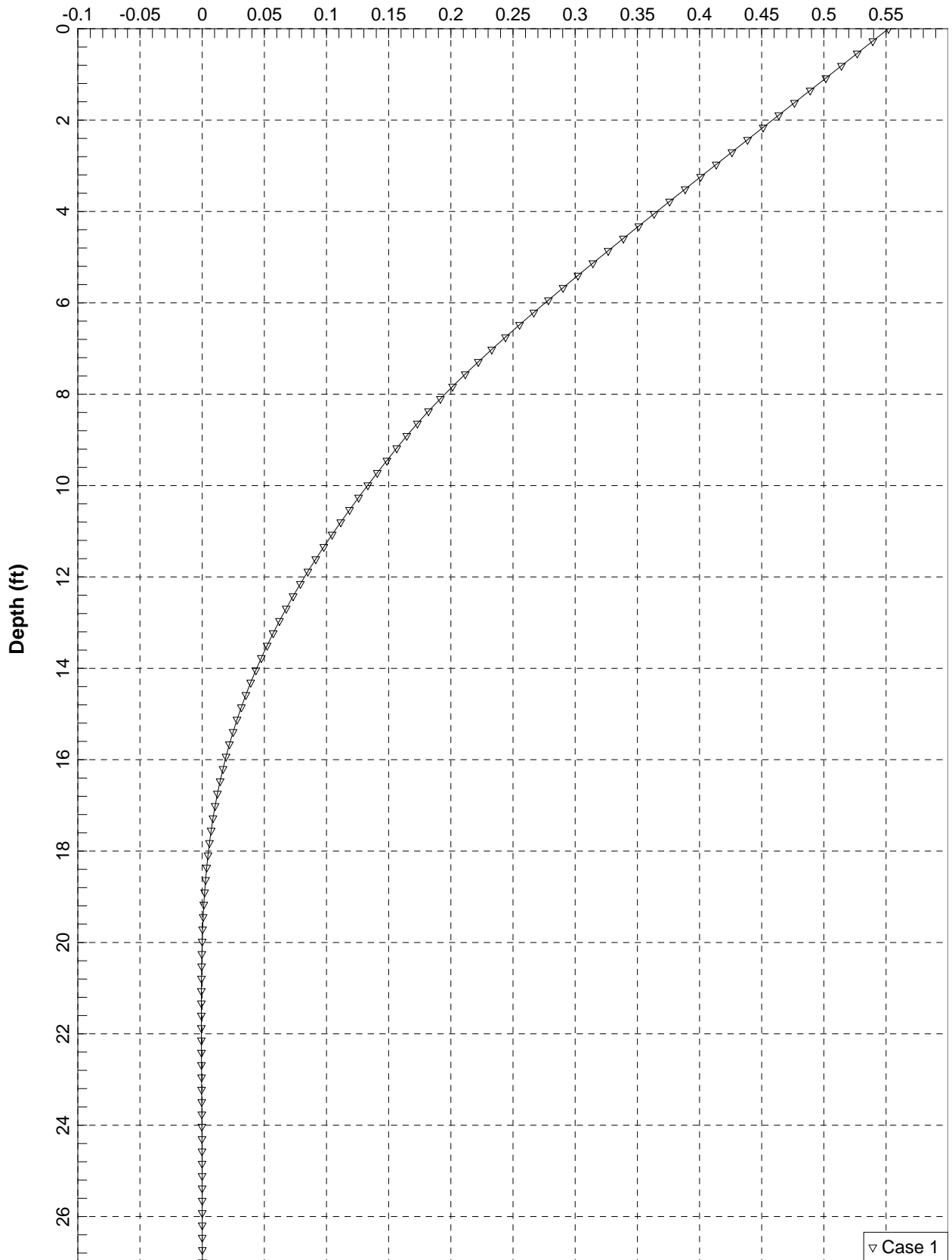
Shear	=	0. lbs
Moment	=	0. in-lbs
Axial Load	=	0. lbs

Pile Length in	Pile Head Deflection in	Maximum Moment in-lbs	Maximum Shear lbs
324.000	.55198474	1189762.	16248.64716
307.800	.55542135	1190057.	16239.98691
291.600	.55573694	1190317.	16242.52355

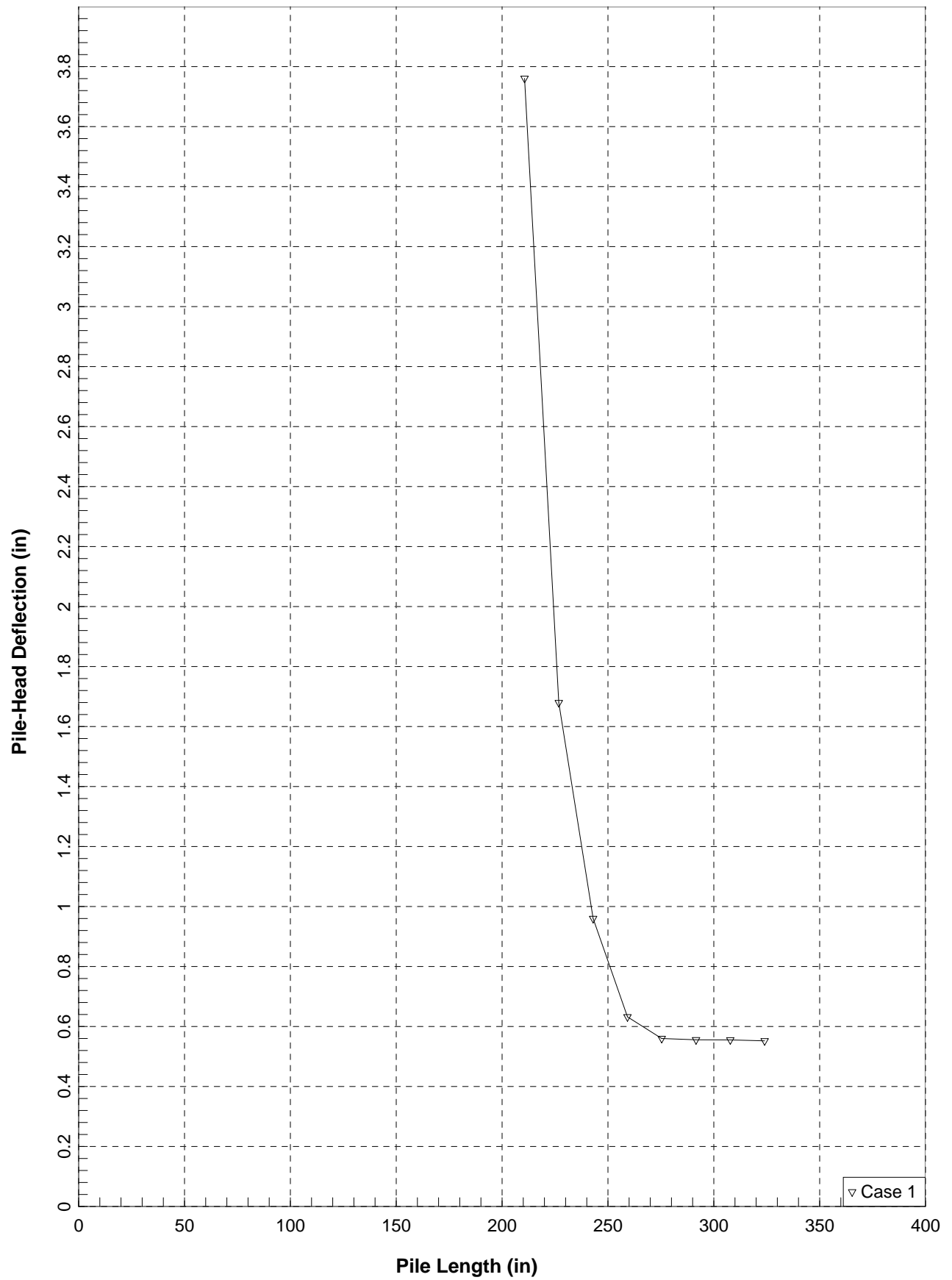
275.400	.56019077	Retaining Wall S - Pile and Lagging - 9.0 ft Wall Ht. Ipo	1186663.	16254.34917
259.200	.63233315		1162569.	-18135.86542
243.000	.95991374		1112953.	-21111.48754
226.800	1.67941751		1064494.	-24075.02481
210.600	3.76083955		1009004.	-27350.94023

The analysis ended normally.

### Lateral Deflection (in)



▽ Case 1



Retaining Wall S - Pile and Lagging - 9.0 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

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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 S\Revised Analysis - 8-8-13\9 ft Wall Ht\  
Name of input data file: Retaining Wall S - Pile and Lagging - 9.0 ft Wall Ht.lpd  
Name of output file: Retaining Wall S - Pile and Lagging - 9.0 ft Wall Ht.lpo  
Name of plot output file: Retaining Wall S - Pile and Lagging - 9.0 ft Wall Ht.lpp  
Name of runtime file: Retaining Wall S - Pile and Lagging - 9.0 ft Wall Ht.lpr

Time and Date of Analysis

Date: August 9, 2013 Time: 10:20:42

Problem Title

HAM-75-7.85 - Retaining Wall S - Pile and Lagging - 9 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 = 324.00 in

Retaining Wall S - Pile and Lagging - 9.0 ft Wall Ht. I po

Depth of ground surface below top of pile = 108.00 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	11.80000000	393.0000	15.5000	29000000.
2	108.0000	11.80000000	393.0000	15.5000	29000000.
3	108.0000	24.00000000	16286.0000	452.4000	3122019.
4	324.0000	24.00000000	16286.0000	452.4000	3122019.

Soil and Rock Layering Information

The soil profile is modelled using 3 layers

Layer 1 is sand, p-y criteria by Reese et al., 1974

Distance from top of pile to top of layer = 108.000 in  
 Distance from top of pile to bottom of layer = 246.000 in  
 p-y subgrade modulus k for top of soil layer = 225.000 lbs/in\*\*3  
 p-y subgrade modulus k for bottom of layer = 225.000 lbs/in\*\*3

Layer 2 is stiff clay without free water

Distance from top of pile to top of layer = 246.000 in  
 Distance from top of pile to bottom of layer = 360.000 in

Layer 3 is sand, p-y criteria by Reese et al., 1974

Distance from top of pile to top of layer = 360.000 in  
 Distance from top of pile to bottom of layer = 390.000 in  
 p-y subgrade modulus k for top of soil layer = 225.000 lbs/in\*\*3  
 p-y subgrade modulus k for bottom of layer = 225.000 lbs/in\*\*3

(Depth of lowest layer extends 66.00 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	108.00	.07500
2	246.00	.07500
3	246.00	.07200
4	360.00	.07200
5	360.00	.07800
6	390.00	.07800

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 <sub>rm</sub>	RQD %
1	108.000	.00000	34.00	-----	-----
2	246.000	.00000	34.00	-----	-----
3	246.000	27.80000	.00	.00500	.0
4	360.000	27.80000	.00	.00500	.0
5	360.000	.00000	35.00	-----	-----
6	390.000	.00000	35.00	-----	-----

Notes:

Retaining Wall S - Pile and Lagging - 9.0 ft Wall Ht.lpo

- (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<sub>rm</sub> 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	108.000	1.0000	1.0000
2	390.000	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	108.000	452.40000

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	.963919	1.2053E-07	0.0000	-.0064425	1.8095E-09	0.0000	0.0000
3.240	.943045	8.9046	24.7350	-.0064425	.1336822	0.0000	0.0000

	Retaining Wall	S - Pile and	Lagging -	9.0 ft Wall	Ht. Ipo		
6. 480	. 922172	160. 2826	90. 6949	- .0064424	2. 4063	0. 0000	0. 0000
9. 720	. 901298	596. 6075	200. 6281	- .0064423	8. 9567	0. 0000	0. 0000
12. 960	. 880426	1460. 3526	354. 5346	- .0064420	21. 9239	0. 0000	0. 0000
16. 200	. 859554	2893. 9915	552. 4143	- .0064414	43. 4467	0. 0000	0. 0000
19. 440	. 838685	5039. 9975	794. 2674	- .0064403	75. 6641	0. 0000	0. 0000
22. 680	. 817821	8040. 8440	1080. 0937	- .0064384	120. 7150	0. 0000	0. 0000
25. 920	. 796964	12039. 0046	1409. 8933	- .0064356	180. 7382	0. 0000	0. 0000
29. 160	. 776118	17176. 9526	1783. 6662	- .0064314	257. 8728	0. 0000	0. 0000
32. 400	. 755288	23597. 1614	2201. 4123	- .0064256	354. 2576	0. 0000	0. 0000
35. 640	. 734480	31442. 1045	2663. 1318	- .0064178	472. 0316	0. 0000	0. 0000
38. 880	. 713701	40854. 2553	3168. 8245	- .0064075	613. 3336	0. 0000	0. 0000
42. 120	. 692959	51976. 0872	3718. 4905	- .0063943	780. 3026	0. 0000	0. 0000
45. 360	. 672266	64950. 0736	4312. 1298	- .0063777	975. 0774	0. 0000	0. 0000
48. 600	. 651632	79918. 6881	4949. 7423	- .0063571	1199. 7971	0. 0000	0. 0000
51. 840	. 631071	97024. 4039	5631. 3282	- .0063320	1456. 6005	0. 0000	0. 0000
55. 080	. 610600	116410. 0000	6356. 8873	- .0063016	1747. 6265	0. 0000	0. 0000
58. 320	. 590237	138217. 0000	7126. 4197	- .0062654	2075. 0140	0. 0000	0. 0000
61. 560	. 570000	162589. 0000	7939. 9254	- .0062227	2440. 9020	0. 0000	0. 0000
64. 800	. 549914	189668. 0000	8797. 4043	- .0061726	2847. 4293	0. 0000	0. 0000
68. 040	. 530002	219596. 0000	9698. 8566	- .0061144	3296. 7350	0. 0000	0. 0000
71. 280	. 510292	252516. 0000	10644. 2821	- .0060473	3790. 9578	0. 0000	0. 0000
74. 520	. 490815	288571. 0000	11633. 6809	- .0059704	4332. 2367	0. 0000	0. 0000
77. 760	. 471604	327903. 0000	12667. 0530	- .0058828	4922. 7107	0. 0000	0. 0000
81. 000	. 452695	370654. 0000	13744. 3983	- .0057835	5564. 5186	0. 0000	0. 0000
84. 240	. 434127	416966. 0000	14865. 7170	- .0056715	6259. 7993	0. 0000	0. 0000
87. 480	. 415943	466983. 0000	16031. 0089	- .0055459	7010. 6918	0. 0000	0. 0000
90. 720	. 398189	520847. 0000	17240. 2741	- .0054055	7819. 3350	0. 0000	0. 0000
93. 960	. 380915	578700. 0000	18493. 5126	- .0052492	8687. 8678	0. 0000	0. 0000
97. 200	. 364174	640685. 0000	19790. 7243	- .0050759	9618. 4291	0. 0000	0. 0000
100. 440	. 348024	706944. 0000	21131. 9094	- .0048843	10613. 1578	0. 0000	0. 0000
103. 680	. 332524	777620. 0000	22517. 0677	- .0046733	11674. 1929	0. 0000	0. 0000
106. 920	. 317741	852855. 0000	23823. 7459	- .0044415	12803. 6732	0. 0000	0. 0000
110. 160	. 303743	931998. 0000	24384. 1125	- .0042906	686. 7232	-26. 3822	281. 4167
113. 400	. 289938	1010864. 0000	24229. 6652	- .0042287	744. 8340	-68. 9556	770. 5669
116. 640	. 276341	1089006. 0000	23933. 3348	- .0041618	802. 4114	-113. 9643	1336. 1917
119. 880	. 262969	1165952. 0000	23489. 3293	- .0040900	859. 1074	-160. 1132	1972. 7289
123. 120	. 249838	1241217. 0000	22894. 1417	- .0040133	914. 5648	-207. 2866	2688. 1762
126. 360	. 236963	1314306. 0000	22146. 9438	- .0039318	968. 4190	-253. 9467	3472. 2167
129. 600	. 224360	1384729. 0000	21251. 1127	- .0038458	1020. 3088	-299. 0355	4318. 4012
132. 840	. 212042	1452013. 0000	20212. 7259	- .0037555	1069. 8857	-341. 9440	5224. 9012
136. 080	. 200024	1515708. 0000	19038. 6641	- .0036609	1116. 8176	-382. 7854	6200. 3728
139. 320	. 188319	1575384. 0000	17738. 3803	- .0035624	1160. 7887	-419. 8589	7223. 5944
142. 560	. 176940	1630652. 0000	16325. 3373	- .0034603	1201. 5122	-452. 3900	8283. 8565
145. 800	. 165897	1681172. 0000	14810. 7160	- .0033548	1238. 7365	-482. 5615	9424. 5286
149. 040	. 155201	1726626. 0000	13202. 6660	- .0032462	1272. 2282	-510. 0620	10648. 1358
152. 280	. 144862	1766725. 0000	11514. 1061	- .0031349	1301. 7746	-532. 2590	11904. 5995
155. 520	. 134887	1801237. 0000	9763. 0589	- .0030212	1327. 2041	-548. 6344	13178. 2578
158. 760	. 125284	1829990. 0000	7960. 4637	- .0029055	1348. 3899	-564. 0787	14587. 7472
162. 000	. 116059	1852821. 0000	6115. 3161	- .0027882	1365. 2125	-574. 9013	16049. 3743
165. 240	. 107217	1869617. 0000	4244. 4380	- .0026696	1377. 5884	-579. 9618	17525. 9154
168. 480	. 098761	1880325. 0000	2366. 2480	- .0025501	1385. 4782	-579. 4148	19008. 6215
171. 720	. 090693	1884950. 0000	496. 2966	- .0024301	1388. 8864	-574. 8762	20537. 5166
174. 960	. 083014	1883541. 0000	-1348. 4497	- .0023100	1387. 8479	-563. 8561	22007. 1772
178. 200	. 075723	1876212. 0000	-3146. 8695	- .0021902	1382. 4480	-546. 2795	23373. 8103
181. 440	. 068821	1863149. 0000	-4886. 6207	- .0020711	1372. 8227	-527. 6410	24840. 7237
184. 680	. 062303	1844547. 0000	-6567. 7595	- .0019530	1359. 1161	-510. 0990	26527. 2803
187. 920	. 056165	1820590. 0000	-8183. 4983	- .0018362	1341. 4639	-487. 2706	28109. 0338
191. 160	. 050404	1791518. 0000	-9717. 1948	- .0017211	1320. 0427	-459. 4556	29534. 0203
194. 400	. 045013	1757623. 0000	-11153. 4117	- .0016080	1295. 0677	-427. 0980	30742. 4061
197. 640	. 039984	1719244. 0000	-12478. 3979	- .0014973	1266. 7891	-390. 7948	31666. 9809
200. 880	. 035310	1676763. 0000	-13680. 5934	- .0013891	1235. 4877	-351. 3012	32234. 5227
204. 120	. 030983	1630594. 0000	-14752. 9635	- .0012837	1201. 4690	-310. 6556	32486. 3070
207. 360	. 026992	1581163. 0000	-15738. 2683	- .0011813	1165. 0474	-297. 5572	35717. 1154
210. 600	. 023328	1528610. 0000	-16678. 1788	- .0010823	1126. 3242	-282. 6344	39254. 9073
213. 840	. 019979	1473089. 0000	-17567. 0162	- .0009866	1085. 4149	-266. 0306	43141. 8292
217. 080	. 016935	1414775. 0000	-18399. 6002	- .0008946	1042. 4478	-247. 9101	47431. 1885
220. 320	. 014182	1353859. 0000	-19171. 3132	- .0008064	997. 5631	-228. 4559	52192. 2830
223. 560	. 011709	1290545. 0000	-19878. 1559	- .0007221	950. 9114	-207. 8668	57518. 1470
226. 800	. 009503	1225049. 0000	-20516. 7917	- .0006420	902. 6518	-186. 3528	63538. 5703
230. 040	. 007549	1157596. 0000	-21090. 7351	- .0005661	852. 9509	-167. 9333	72076. 0202
233. 280	. 005834	1088381. 0000	-21606. 7009	- .0004945	801. 9509	-150. 5641	83611. 8997
236. 520	. 004345	1017585. 0000	-22054. 1370	- .0004274	749. 7864	-125. 6311	93691. 0800
239. 760	. 003065	945470. 0000	-22404. 8483	- .0003649	696. 6501	-90. 8574	96053. 0400
243. 000	. 001980	872402. 0000	-22649. 4757	- .0003070	642. 8110	-60. 1471	98415. 0000
246. 240	. 001076	798702. 0000	-23415. 5113	- .0002537	588. 5067	-412. 7144	1243118.
249. 480	. 000336	720669. 0000	-24472. 4704	- .0002053	531. 0100	-239. 7295	2310956.
252. 720	- .000255	640120. 0000	-24562. 1994	- .0001619	471. 6591	184. 3413	2345188.
255. 960	- .000713	561506. 0000	-23633. 0598	- .0001237	413. 7341	389. 2016	1767861.
259. 200	- .001056	486978. 0000	-22297. 0504	-9. 0253E-05	358. 8194	435. 4955	1336191.

Retaining Wall S - Pile and Lagging - 9.0 ft Wall Ht. I po								
262.440	- .001298	417021.	-20838.1333	-6.1451E-05	307.2734	465.0706	1160759.	
265.680	- .001454	351947.	-19298.7740	-3.6950E-05	259.3246	485.1512	1080938.	
268.920	- .001538	291965.	-17704.8576	-1.6434E-05	215.1284	498.7477	1050966.	
272.160	- .001561	237219.	-16074.8621	4.2624E-07	174.7900	507.4223	1053414.	
275.400	- .001535	187800.	-14423.2538	1.3968E-05	138.3765	512.0890	1081021.	
278.640	- .001470	143757.	-12762.0922	2.4532E-05	105.9240	513.3195	1131265.	
281.880	- .001376	105102.	-11101.9176	3.2461E-05	77.4420	511.4797	1204488.	
285.120	- .001260	71816.0987	-9452.3148	3.8098E-05	52.9162	506.7936	1303362.	
288.360	- .001129	43850.6569	-7822.3305	4.1783E-05	32.3104	499.3695	1433118.	
291.600	- .000989	21127.3969	-6220.8473	4.3853E-05	15.5673	489.2004	1602519.	
294.840	- .000845	3539.5666	-4657.0019	4.4639E-05	2.6081	476.1363	1826073.	
298.080	- .000700	-9049.9752	-3140.7584	4.4464E-05	6.6683	459.8164	2128865.	
301.320	- .000557	-16812.5482	-1683.8377	4.3640E-05	12.3880	439.5174	2558068.	
304.560	- .000417	-19961.2437	-368.6589	4.2468E-05	14.7080	372.3214	2892665.	
307.800	- .000281	-19201.4581	646.4475	4.1220E-05	14.1482	254.2875	2926872.	
311.040	- .000150	-15772.2636	1280.3575	4.0106E-05	11.6215	137.0149	2961078.	
314.280	-2.16E-05	-10904.7418	1534.6803	3.9256E-05	8.0349	19.9746	2995282.	
317.520	.000104	-5827.5351	1408.8140	3.8723E-05	4.2939	-97.6699	3029486.	
320.760	.000229	-1775.6274	899.3110	3.8480E-05	1.3083	-216.8382	3063690.	
324.000	.000354	0.0000	0.0000	3.8424E-05	0.0000	-338.2921	1548946.	

Output Veri fi cation:

Computed forces and moments are within speci fied convergence li mi ts.

Output Summary for Load Case No. 1:

Pile-head deflection = .96391909 in  
 Computed slope at pile head = -.00644247  
 Maximum bending moment = 1884950. lbs-in  
 Maximum shear force = -24562.19936 lbs  
 Depth of maximum bending moment = 171.72000 in  
 Depth of maximum shear force = 252.72000 in  
 Number of iterations = 17  
 Number of zero deflection points = 2

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 Summary of Pile Response(s)  
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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	.9639191	1884950.	-24562.1994

-----  
 Pile-head Deflection vs. Pile Length  
 -----

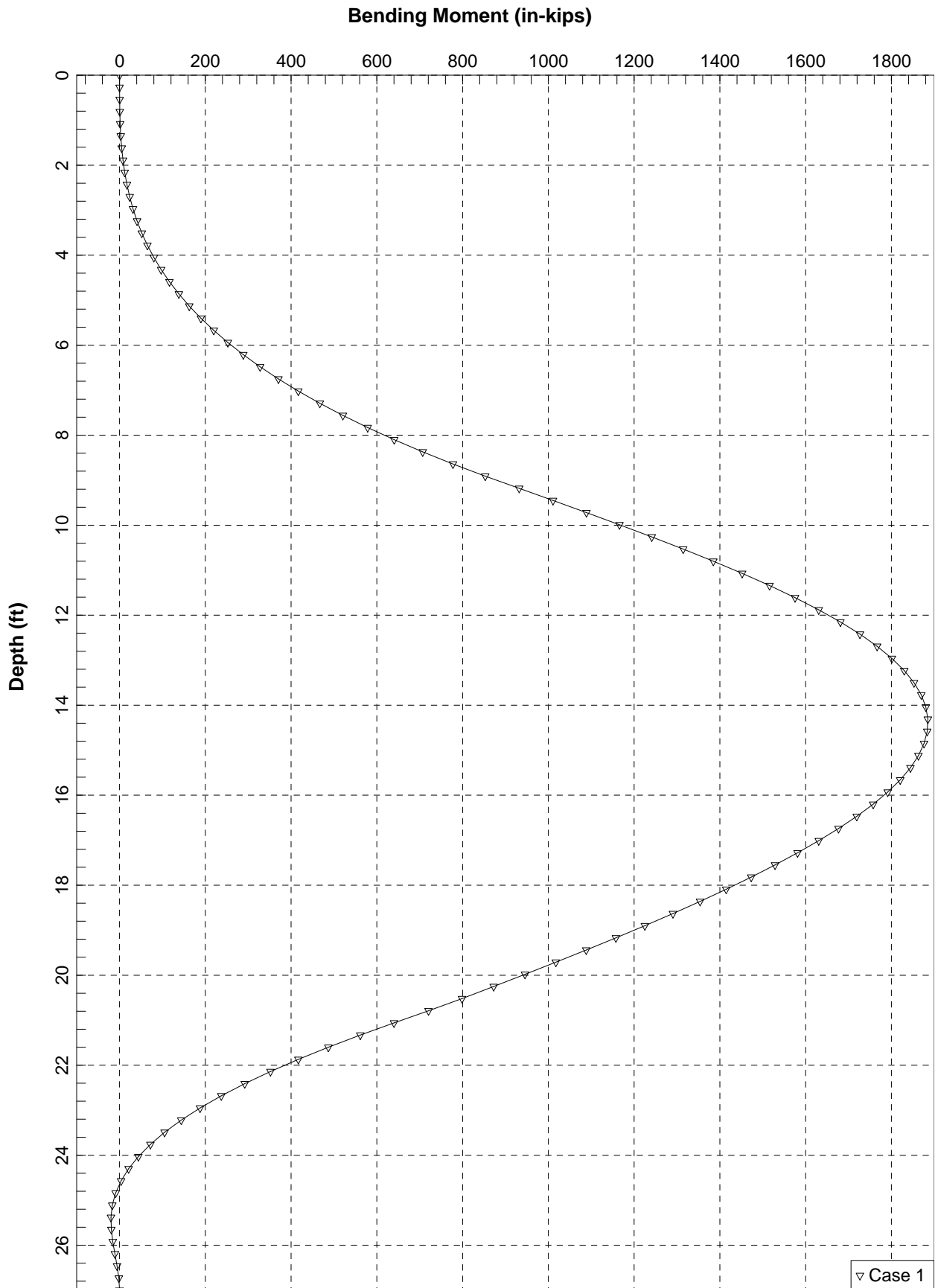
Boundary Condition Type 1, Shear and Moment

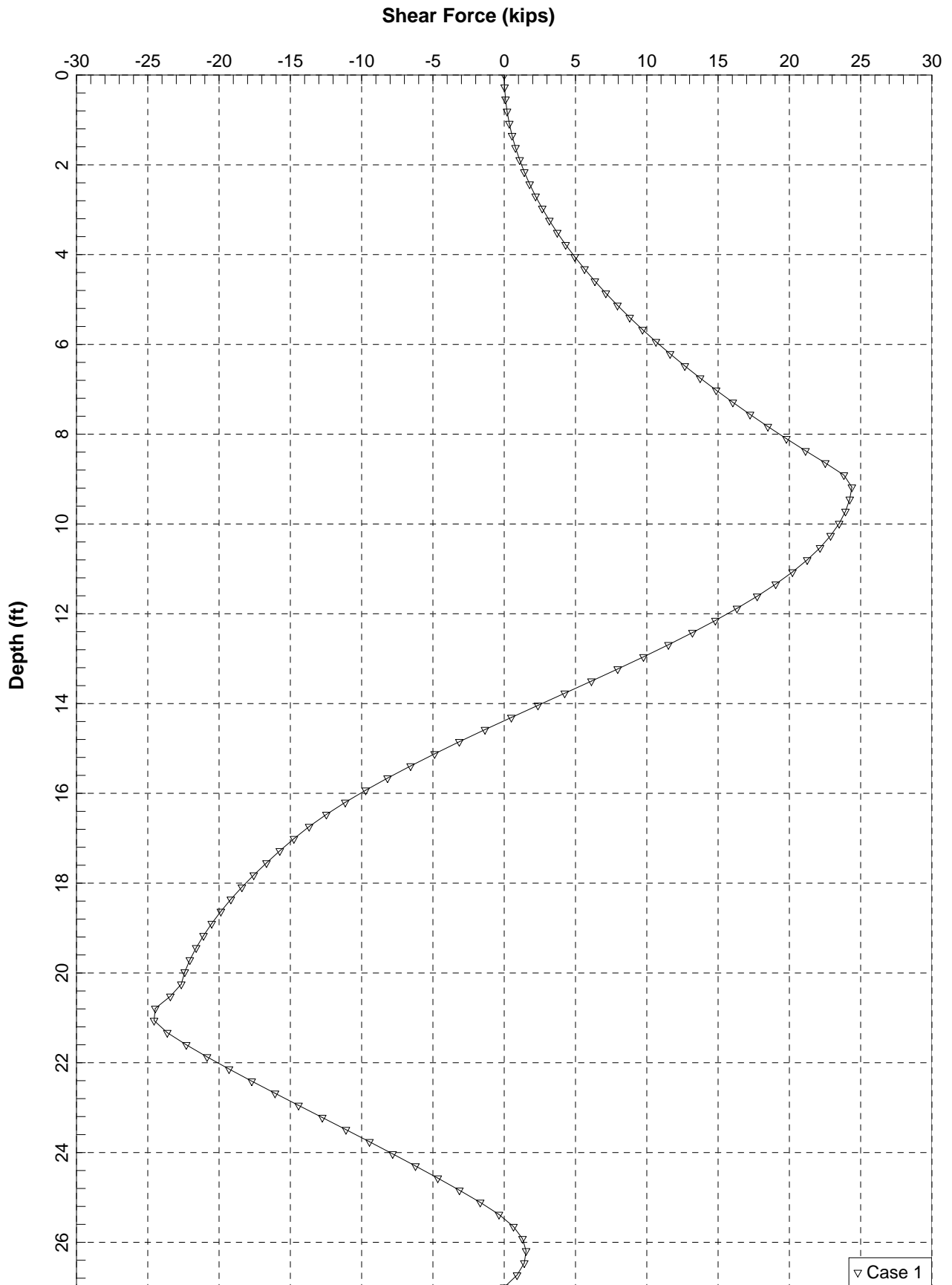
Shear = 0. lbs  
 Moment = 0. in-lbs  
 Axial Load = 0. lbs

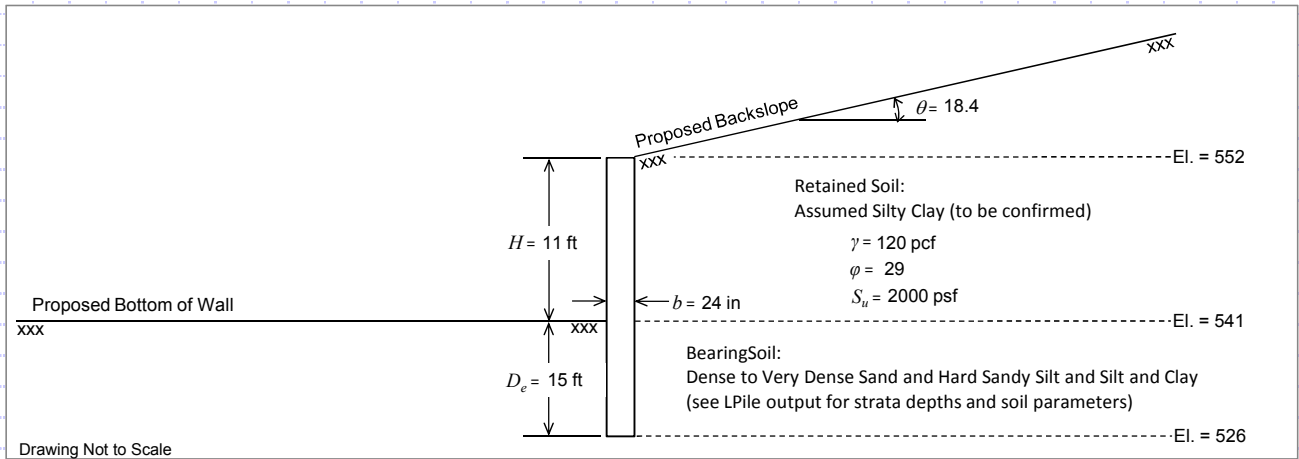
Pile Length in	Pile Head Deflection in	Maximum Moment in-lbs	Maximum Shear lbs
324.000	.96391909	1884950.	-24562.19936
307.800	.96899715	1885430.	-24385.68285
291.600	.98522526	1878218.	-25812.26029

275.400	1.07513155	Retaining Wall S - Pile and Lagging - 9.0 ft Wall Ht. Ipo	1847225.	-28037.03769
259.200	1.41341018		1785619.	-30278.88847
243.000	2.23148836		1702868.	-33621.64905
226.800	4.42253886		1646055.	-38190.07243

The analysis ended normally.







**Retaining Wall and Soil Parameters**

Retaining Wall Height, (H) =	11.0 ft
Soil Friction Angle, ( $\phi'$ ) =	29°
Soil Total Unit Weight, ( $\gamma$ ) =	120 pcf
Soil Undrained Shear Strength, ( $s_u$ ) =	2000 psf
Backslope Angle, ( $\theta$ ) =	18.4°
Embedment Depth, ( $D_e$ ) =	15 ft
Shaft Spacing, (S) =	8.0 ft O.C.
Shaft Diameter, (b) =	24 in

**Rankine Earth Pressures**

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

$$K_a = 0.4189$$

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

$$K_p = 2.1483$$

**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**

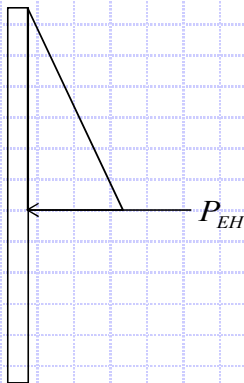
$S/b = 4.00$   
 $\beta_a = 1.0000$

**Structural Element Properties**

Section Type: **HP 12x53**

E = 29,000 ksi	d = 11.8 in	$I_x = 393 \text{ in}^4$	$Z_x = 74 \text{ in}^3$
$A_s = 15.5 \text{ in}^2$	$t_w = 0.435 \text{ in}$	$I_x = 49.1 \text{ in}^4 \text{ per ft}$	$Z_x = 9.3 \text{ in}^3 \text{ per ft}$
$f_y = 50 \text{ ksi}$	$t_f = 0.435 \text{ in}$	$r_s = 5.03 \text{ in}$	T = 9.5 in
			S = 66.8 in <sup>3</sup>

**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.

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

$$P_{EH} = (120 \text{ pcf})(11.0 \text{ ft})(8 \text{ ft O.C.})(0.419)(1.00) \quad (\text{Service I})$$

$$= (120 \text{ pcf})(11.0 \text{ ft})(8 \text{ ft O.C.})(0.419)(1.50) \quad (\text{Strength I})$$

$$P_{EH} = 4423.9 \text{ lb/ft} \quad (\text{Service I})$$

$$= 6635.8 \text{ lb/ft} \quad (\text{Strength I})$$

**Check Deflection - (Loading Case - Service I)**

$$\left(\frac{\delta_h}{H}\right) \cdot 100\% < 1.0\% \quad \longrightarrow \quad \delta_h = 1.372 \text{ in} \quad (\text{Determined from LPILE}) \quad \longrightarrow \quad 1.0\% \leq 1.0\% \quad \text{OK}$$

**Capacity Verification - (Loading Case - Strength I)**

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

Maximum Bending Moment,  $M_u = 260.9$  kip-ft per section (Determined from LPILE analysis)

Maximum Shear Force,  $V_u = 52.1$  kip per section (Determined from LPILE analysis)

Factored Flexural Resistance,  $\phi_f M_n = 308.3$  kip-ft per section  $\longrightarrow M_u < \phi_f M_n \longrightarrow 260.9 \text{ kip-ft} < 308.3 \text{ kip-ft}$  **OK**

Factored Shear Resistance,  $\phi_v V_n = 148.6$  kip per section  $\longrightarrow V_u < \phi_v V_n \longrightarrow 52.1 \text{ kip} < 148.6 \text{ kip}$  **OK**

$S_{Req} = M_u \times \left(\frac{12}{50 \text{ ksi}}\right) = (260.9 \text{ kip-ft})(12 \text{ in}) / (50 \text{ ksi}) = 62.6 \text{ in}^3 \longrightarrow S_{Req} < S_{Section} \longrightarrow 62.6 \text{ in}^3 < 66.8 \text{ in}^3$  **OK**

Retaining Wall S - Pile and Lagging - 9.5 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

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This program is licensed to:

Path to file locations: J:\GEO TECH\Projects\2010\B-10-020 HAM-75-7.85\HAM-75-7.85 PID 77889 -  
Mainline\Analysis\Retaining Wall S\  
Name of input data file: Retaining Wall S - Pile and Lagging - 9.5 ft Wall Ht.lpd  
Name of output file: Retaining Wall S - Pile and Lagging - 9.5 ft Wall Ht.lpo  
Name of plot output file: Retaining Wall S - Pile and Lagging - 9.5 ft Wall Ht.lpp  
Name of runtime file: Retaining Wall S - Pile and Lagging - 9.5 ft Wall Ht.lpr

Time and Date of Analysis

Date: August 8, 2013 Time: 13:08:16

Problem Title

HAM-75-7.85 - Retaining Wall S - Pile and Lagging - 11 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 = 360.00 in

Retaining Wall S - Pile and Lagging - 9.5 ft Wall Ht. I po

Depth of ground surface below top of pile = 132.00 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	11.80000000	393.0000	15.5000	29000000.
2	132.0000	11.80000000	393.0000	15.5000	29000000.
3	132.0000	24.00000000	16286.0000	452.4000	3122019.
4	360.0000	24.00000000	16286.0000	452.4000	3122019.

Soil and Rock Layering Information

The soil profile is modelled using 3 layers

Layer 1 is sand, p-y criteria by Reese et al., 1974

Distance from top of pile to top of layer = 132.000 in  
 Distance from top of pile to bottom of layer = 246.000 in  
 p-y subgrade modulus k for top of soil layer = 225.000 lbs/in\*\*3  
 p-y subgrade modulus k for bottom of layer = 225.000 lbs/in\*\*3

Layer 2 is stiff clay without free water

Distance from top of pile to top of layer = 246.000 in  
 Distance from top of pile to bottom of layer = 360.000 in

Layer 3 is sand, p-y criteria by Reese et al., 1974

Distance from top of pile to top of layer = 360.000 in  
 Distance from top of pile to bottom of layer = 390.000 in  
 p-y subgrade modulus k for top of soil layer = 225.000 lbs/in\*\*3  
 p-y subgrade modulus k for bottom of layer = 225.000 lbs/in\*\*3

(Depth of lowest layer extends 30.00 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	132.00	.07500
2	246.00	.07500
3	246.00	.07200
4	360.00	.07200
5	360.00	.07800
6	390.00	.07800

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 <sub>rm</sub>	RQD %
1	132.000	.00000	34.00	-----	-----
2	246.000	.00000	34.00	-----	-----
3	246.000	27.80000	.00	.00500	.0
4	360.000	27.80000	.00	.00500	.0
5	360.000	.00000	35.00	-----	-----
6	390.000	.00000	35.00	-----	-----

Notes:

Retaining Wall S - Pile and Lagging - 9.5 ft Wall Ht. Ipo

- (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<sub>rm</sub> 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	132.000	1.0000	1.0000
2	390.000	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	132.000	368.70000

-----  
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	1.283	5.0769E-06	2.7120E-08	-.0077971	7.6218E-08	0.0000	0.0000
3.600	1.254	8.1449	20.3623	-.0077970	.1222774	0.0000	0.0000

Retaining Wall S - Pile and Lagging - 9.5 ft Wall Ht. I po

7.200	1.226	146.6085	74.6617	-	0077970	2.2010	0.0000	0.0000
10.800	1.198	545.7095	165.1608	-	0077969	8.1926	0.0000	0.0000
14.400	1.170	1335.7666	291.8596	-	0077966	20.0535	0.0000	0.0000
18.000	1.142	2647.0984	454.7579	-	0077960	39.7402	0.0000	0.0000
21.600	1.114	4610.0237	653.8559	-	0077948	69.2090	0.0000	0.0000
25.200	1.086	7354.8611	889.1536	-	0077930	110.4165	0.0000	0.0000
28.800	1.058	11011.9294	1160.6508	-	0077901	165.3190	0.0000	0.0000
32.400	1.030	15711.5472	1468.3477	-	0077858	235.8731	0.0000	0.0000
36.000	1.002	21584.0332	1812.2443	-	0077799	324.0351	0.0000	0.0000
39.600	.973982	28759.7061	2192.3405	-	0077720	431.7615	0.0000	0.0000
43.200	.946019	37368.8846	2608.6363	-	0077615	561.0087	0.0000	0.0000
46.800	.918099	47541.8874	3061.1317	-	0077481	713.7332	0.0000	0.0000
50.400	.890233	59409.0332	3549.8268	-	0077312	891.8913	0.0000	0.0000
54.000	.862434	73100.6407	4074.7216	-	0077103	1097.4396	0.0000	0.0000
57.600	.834718	88747.0285	4635.8159	-	0076848	1332.3345	0.0000	0.0000
61.200	.807104	106479.	5233.1099	-	0076539	1598.5324	0.0000	0.0000
64.800	.779610	126425.	5866.6036	-	0076171	1897.9898	0.0000	0.0000
68.400	.752260	148718.	6536.2968	-	0075737	2232.6630	0.0000	0.0000
72.000	.725080	173487.	7242.1897	-	0075228	2604.5086	0.0000	0.0000
75.600	.698096	200862.	7984.2823	-	0074637	3015.4829	0.0000	0.0000
79.200	.671341	230974.	8762.5745	-	0073955	3467.5424	0.0000	0.0000
82.800	.644849	263952.	9577.0663	-	0073173	3962.6436	0.0000	0.0000
86.400	.618657	299928.	10427.7577	-	0072282	4502.7429	0.0000	0.0000
90.000	.592805	339032.	11314.6488	-	0071273	5089.7967	0.0000	0.0000
93.600	.567340	381394.	12237.7396	-	0070135	5725.7614	0.0000	0.0000
97.200	.542308	427144.	13197.0299	-	0068859	6412.5936	0.0000	0.0000
100.800	.517762	476413.	14192.5199	-	0067431	7152.2495	0.0000	0.0000
104.400	.493757	529330.	15224.2096	-	0065843	7946.6858	0.0000	0.0000
108.000	.470355	586027.	16292.0988	-	0064081	8797.8588	0.0000	0.0000
111.600	.447619	646633.	17396.1877	-	0062135	9707.7249	0.0000	0.0000
115.200	.425618	711279.	18536.4763	-	0059990	10678.2406	0.0000	0.0000
118.800	.404426	780096.	19712.9645	-	0057635	11711.3623	0.0000	0.0000
122.400	.384121	853213.	20925.6523	-	0055055	12809.0465	0.0000	0.0000
126.000	.364786	930761.	22174.5397	-	0052237	13973.2496	0.0000	0.0000
129.600	.346510	1012869.	23459.6268	-	0049168	15205.9281	0.0000	0.0000
133.200	.329385	1099670.	24195.1480	-	0047179	810.2688	-14.6838	160.4860
136.800	.312541	1187075.	24167.5866	-	0046369	874.6711	-61.9385	713.4371
140.400	.295999	1273676.	23853.4601	-	0045498	938.4820	-112.5763	1369.1731
144.000	.279782	1358819.	23354.2003	-	0044566	1001.2178	-164.7903	2120.3796
147.600	.263912	1441827.	22664.9196	-	0043575	1062.3800	-218.1434	2975.6762
151.200	.248409	1522007.	21785.1828	-	0042525	1121.4591	-270.5992	3921.5905
154.800	.233294	1598680.	20720.7793	-	0041421	1177.9541	-320.7361	4949.3434
158.400	.218586	1671196.	19480.3839	-	0040263	1231.3863	-368.3725	6066.9116
162.000	.204304	1738939.	18075.2624	-	0039056	1281.3008	-412.2506	7264.1814
165.600	.190466	1801338.	16521.8020	-	0037803	1327.2787	-450.7829	8520.2700
169.200	.177086	1857896.	14837.6341	-	0036507	1368.9518	-484.8659	9856.8740
172.800	.164181	1908169.	13035.2124	-	0035174	1405.9948	-516.4795	11324.8886
176.400	.151761	1951749.	11130.9411	-	0033807	1438.1058	-541.4491	12843.9792
180.000	.139839	1988312.	9150.0419	-	0032413	1465.0464	-559.0505	14392.1152
183.600	.128424	2017630.	7107.2505	-	0030994	1486.6484	-575.8336	16141.8388
187.200	.117523	2039484.	5016.6681	-	0029558	1502.7515	-585.6011	17938.2711
190.800	.107142	2053750.	2904.2494	-	0028109	1513.2626	-587.9649	19755.7300
194.400	.097285	2060395.	793.4704	-	0026653	1518.1591	-584.6902	21636.3261
198.000	.087952	2059463.	-1292.8001	-	0025194	1517.4721	-574.3490	23508.8054
201.600	.079145	2051087.	-3326.9313	-	0023739	1511.3005	-555.7239	25277.7219
205.200	.070860	2035509.	-5287.3666	-	0022292	1499.8222	-533.4068	27099.2467
208.800	.063095	2013018.	-7170.6662	-	0020859	1483.2502	-512.8707	29262.9138
212.400	.055842	1983880.	-8967.8956	-	0019444	1461.7806	-485.5901	31304.8113
216.000	.049095	1948449.	-10655.5858	-	0018052	1435.6740	-452.0156	33145.0080
219.600	.042845	1907160.	-12212.3210	-	0016687	1405.2509	-412.8373	34688.3910
223.200	.037081	1860520.	-13619.6339	-	0015353	1370.8855	-369.0031	35825.0601
226.800	.031791	1809098.	-14862.9454	-	0014054	1332.9964	-321.7255	36432.6270
230.400	.026962	1753507.	-15972.0739	-	0012793	1292.0351	-294.4569	39316.7686
234.000	.022580	1694099.	-16998.6914	-	0011572	1248.2618	-275.8861	43985.8927
237.600	.018630	1631116.	-17954.2679	-	0010395	1201.8541	-254.9897	49274.3220
241.200	.015095	1564829.	-18830.8415	-	0009264	1153.0114	-231.9956	55327.4410
244.800	.011960	1495534.	-19621.3218	-	0008180	1101.9533	-207.1601	62356.8363
248.400	.009206	1423555.	-21120.3974	-	0007147	1048.9170	-625.6597	244676.
252.000	.006814	1343467.	-23310.9140	-	0006167	989.9060	-591.2940	312390.
255.600	.004765	1255717.	-25366.5888	-	0005247	925.2486	-550.7475	416085.
259.200	.003036	1160828.	-27259.8047	-	0004392	855.3319	-501.0391	594080.
262.800	.001603	1059446.	-28944.3334	-	0003606	780.6307	-434.8102	976396.
266.400	.000440	952429.	-30266.9538	-	0002893	701.7773	-299.9789	2453452.
270.000	-.000480	841524.	-30208.7227	-	0002258	620.0594	332.3295	2492153.
273.600	-.001186	734926.	-28847.2761	-	0001700	541.5149	424.0297	1287333.
277.200	-.001704	633823.	-27234.2678	-	0001216	467.0196	472.0860	997252.
280.800	-.002061	538839.	-25478.7348	-8.0048E-05		397.0325	503.2100	878952.
284.400	-.002281	450377.	-23628.9661	-4.5029E-05		331.8506	524.4393	827865.
288.000	-.002385	368711.	-21715.1735	-1.6032E-05		271.6768	538.7788	813167.

Retaining Wall S - Pile and Lagging - 9.5 ft Wall Ht. lpo							
291.600	- .002396	294027.	-19759.3158	7.4303E-06	216.6479	547.8088	823095.
295.200	- .002332	226444.	-17778.8217	2.5856E-05	166.8503	552.4657	852955.
298.800	- .002210	166020.	-15788.3571	3.9750E-05	122.3283	553.3480	901460.
302.400	- .002046	112767.	-13800.7874	4.9619E-05	83.0903	550.8574	969464.
306.000	- .001853	66654.1703	-11827.7592	5.5971E-05	49.1127	545.2694	1059604.
309.600	- .001643	27607.5831	-9880.0864	5.9308E-05	20.3421	536.7710	1176442.
313.200	- .001426	-4482.4520	-7968.0397	6.0127E-05	3.3028	525.4772	1327026.
316.800	- .001210	-29762.3025	-6101.6017	5.8914E-05	21.9297	511.4328	1522061.
320.400	- .001001	-48413.9845	-4290.7508	5.6147E-05	35.6728	494.5955	1778145.
324.000	- .000805	-60655.7086	-2545.8531	5.2286E-05	44.6929	474.7921	2122264.
327.600	- .000625	-66744.1265	-878.3142	4.7775E-05	49.1790	451.6183	2601766.
331.200	- .000461	-66979.5711	676.0283	4.3041E-05	49.3525	411.9053	3213770.
334.800	- .000315	-61876.7225	1930.2697	3.8480E-05	45.5926	284.8954	3255995.
338.400	- .000184	-53081.6292	2747.1025	3.4410E-05	39.1121	168.9006	3298218.
342.000	-6.72E-05	-42097.5846	3163.4358	3.1040E-05	31.0187	62.3957	3340441.
345.600	3.91E-05	-30304.8915	3209.5554	2.8477E-05	22.3295	-36.7737	3382663.
349.200	.000138	-18988.7858	2907.4012	2.6732E-05	13.9915	-131.0897	3424885.
352.800	.000232	-9371.6029	2269.9346	2.5728E-05	6.9053	-223.0584	3467105.
356.400	.000323	-2645.2566	1301.6115	2.5303E-05	1.9491	-314.8989	3509324.
360.000	.000414	0.0000	0.0000	2.5209E-05	0.0000	-408.2186	1775772.

Output Veri fi cation:

Computed forces and moments are within speci fied convergence li mi ts.

Output Summary for Load Case No. 1:

Pile-head deflection = 1.28255255 in  
 Computed slope at pile head = -.00779705  
 Maximum bending moment = 2060395. lbs-in  
 Maximum shear force = -30266.95380 lbs  
 Depth of maximum bending moment = 194.40000 in  
 Depth of maximum shear force = 266.40000 in  
 Number of iterations = 18  
 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=	0.0000	1.2826	2060395.	-30266.9538

-----  
 Pile-head Deflection vs. Pile Length  
 -----

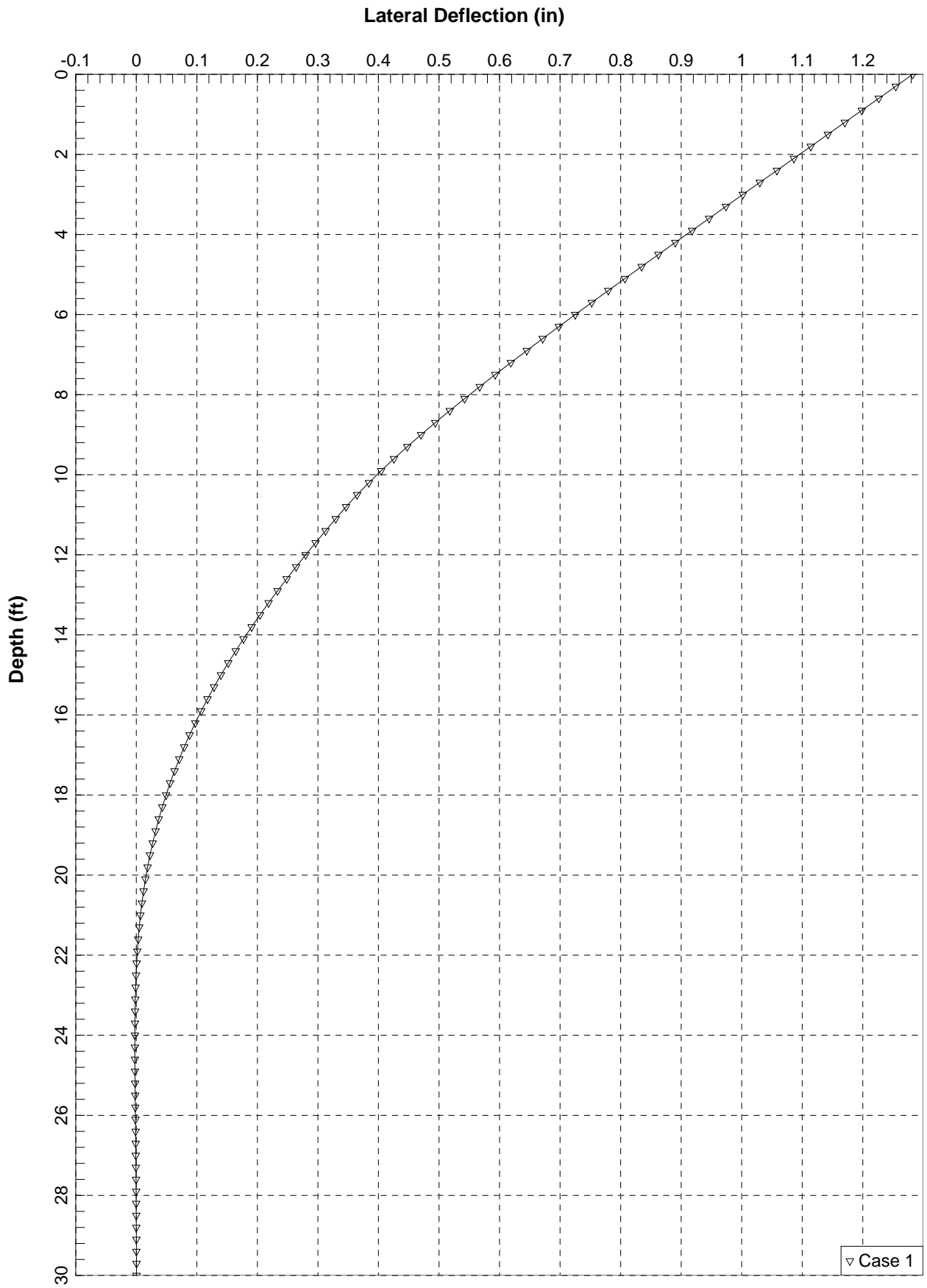
Boundary Condition Type 1, Shear and Moment

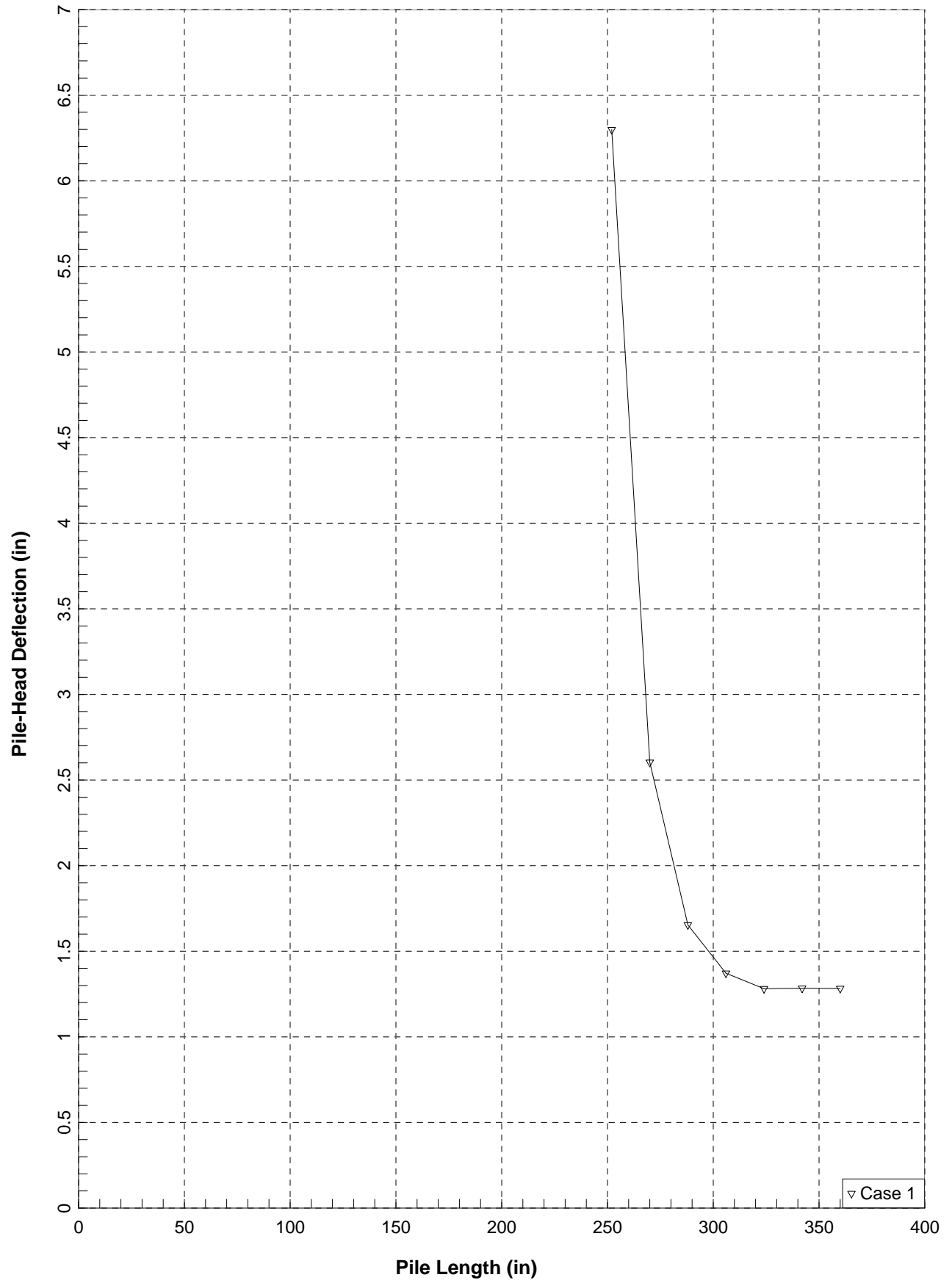
Shear = 0. lbs  
 Moment = 0. in-lbs  
 Axial Load = 0. lbs

Pile Length in	Pile Head Deflection in	Maximum Moment in-lbs	Maximum Shear lbs
360.000	1.28255255	2060395.	-30266.95380
342.000	1.28400692	2061367.	-30358.68305
324.000	1.28128497	2060490.	-30413.35047

306.000	1.37205474	Retaining Wall S - Pile and Lagging - 9.5 ft Wall Ht. Ipo	2037740.	-33242.36914
288.000	1.65404609		1979967.	-34895.91587
270.000	2.60355099		1889569.	-36394.75878
252.000	6.29885821		1832766.	-42474.75059

The analysis ended normally.





Retaining Wall S - Pile and Lagging - 9.5 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

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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 S\  
Name of input data file: Retaining Wall S - Pile and Lagging - 9.5 ft Wall Ht.lpd  
Name of output file: Retaining Wall S - Pile and Lagging - 9.5 ft Wall Ht.lpo  
Name of plot output file: Retaining Wall S - Pile and Lagging - 9.5 ft Wall Ht.lpp  
Name of runtime file: Retaining Wall S - Pile and Lagging - 9.5 ft Wall Ht.lpr

Time and Date of Analysis

Date: August 8, 2013 Time: 13:13:41

Problem Title

HAM-75-7.85 - Retaining Wall S - Pile and Lagging - 11 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 = 360.00 in

Retaining Wall S - Pile and Lagging - 9.5 ft Wall Ht. I po

Depth of ground surface below top of pile = 132.00 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	11.80000000	393.0000	15.5000	29000000.
2	132.0000	11.80000000	393.0000	15.5000	29000000.
3	132.0000	24.00000000	16286.0000	452.4000	3122019.
4	360.0000	24.00000000	16286.0000	452.4000	3122019.

Soil and Rock Layering Information

The soil profile is modelled using 3 layers

Layer 1 is sand, p-y criteria by Reese et al., 1974

Distance from top of pile to top of layer = 132.000 in  
 Distance from top of pile to bottom of layer = 246.000 in  
 p-y subgrade modulus k for top of soil layer = 225.000 lbs/in\*\*3  
 p-y subgrade modulus k for bottom of layer = 225.000 lbs/in\*\*3

Layer 2 is stiff clay without free water

Distance from top of pile to top of layer = 246.000 in  
 Distance from top of pile to bottom of layer = 360.000 in

Layer 3 is sand, p-y criteria by Reese et al., 1974

Distance from top of pile to top of layer = 360.000 in  
 Distance from top of pile to bottom of layer = 390.000 in  
 p-y subgrade modulus k for top of soil layer = 225.000 lbs/in\*\*3  
 p-y subgrade modulus k for bottom of layer = 225.000 lbs/in\*\*3

(Depth of lowest layer extends 30.00 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	132.00	.07500
2	246.00	.07500
3	246.00	.07200
4	360.00	.07200
5	360.00	.07800
6	390.00	.07800

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 <sub>rm</sub>	RQD %
1	132.000	.00000	34.00	-----	-----
2	246.000	.00000	34.00	-----	-----
3	246.000	27.80000	.00	.00500	.0
4	360.000	27.80000	.00	.00500	.0
5	360.000	.00000	35.00	-----	-----
6	390.000	.00000	35.00	-----	-----

Notes:

Retaining Wall S - Pile and Lagging - 9.5 ft Wall Ht. Ipo

- (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<sub>rm</sub> 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	132.000	1.0000	1.0000
2	390.000	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	132.000	553.00000

-----  
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	2.191	0.0000	5.4240E-08	-.0127436	0.0000	0.0000	0.0000
3.600	2.145	12.2163	30.5407	-.0127436	.1833995	0.0000	0.0000

Retaining Wall S - Pile and Lagging - 9.5 ft Wall Ht. Ipo

7.200	2.099	219.8929	111.9825	-	0127436	3.3012	0.0000	0.0000
10.800	2.053	818.4903	247.7189	-	0127434	12.2878	0.0000	0.0000
14.400	2.007	2003.4687	437.7498	-	0127430	30.0775	0.0000	0.0000
18.000	1.961	3970.2886	682.0752	-	0127420	59.6048	0.0000	0.0000
21.600	1.916	6914.4104	980.6952	-	0127403	103.8041	0.0000	0.0000
25.200	1.870	11031.2943	1333.6098	-	0127375	165.6098	0.0000	0.0000
28.800	1.824	16516.4007	1740.8189	-	0127331	247.9561	0.0000	0.0000
32.400	1.778	23565.1901	2202.3225	-	0127268	353.7777	0.0000	0.0000
36.000	1.732	32373.1227	2718.1207	-	0127180	486.0087	0.0000	0.0000
39.600	1.686	43135.6590	3288.2134	-	0127060	647.5837	0.0000	0.0000
43.200	1.641	56048.2593	3912.6007	-	0126904	841.4370	0.0000	0.0000
46.800	1.595	71306.3839	4591.2825	-	0126703	1070.5030	0.0000	0.0000
50.400	1.550	89105.4933	5324.2589	-	0126449	1337.7161	0.0000	0.0000
54.000	1.504	109641.	6111.5298	-	0126135	1646.0106	0.0000	0.0000
57.600	1.459	133109.	6953.0952	-	0125752	1998.3211	0.0000	0.0000
61.200	1.414	159703.	7848.9552	-	0125290	2397.5818	0.0000	0.0000
64.800	1.369	189621.	8799.1098	-	0124738	2846.7273	0.0000	0.0000
68.400	1.324	223057.	9803.5589	-	0124086	3348.6917	0.0000	0.0000
72.000	1.279	260207.	10862.3025	-	0123323	3906.4097	0.0000	0.0000
75.600	1.235	301266.	11975.3407	-	0122436	4522.8154	0.0000	0.0000
79.200	1.191	346429.	13142.6734	-	0121413	5200.8434	0.0000	0.0000
82.800	1.148	395893.	14364.3007	-	0120241	5943.4281	0.0000	0.0000
86.400	1.104	449852.	15640.2225	-	0118905	6753.5037	0.0000	0.0000
90.000	1.062	508502.	16970.4389	-	0117391	7634.0048	0.0000	0.0000
93.600	1.020	572039.	18354.9498	-	0115685	8587.8657	0.0000	0.0000
97.200	.978617	640658.	19793.7552	-	0113770	9618.0207	0.0000	0.0000
100.800	.938024	714554.	21286.8552	-	0111629	10727.4044	0.0000	0.0000
104.400	.898244	793923.	22834.2498	-	0109247	11918.9510	0.0000	0.0000
108.000	.859366	878961.	24435.9389	-	0106605	13195.5950	0.0000	0.0000
111.600	.821488	969862.	26091.9225	-	0103685	14560.2708	0.0000	0.0000
115.200	.784713	1066823.	27802.2007	-	0100468	16015.9128	0.0000	0.0000
118.800	.749152	1170038.	29566.7734	-	0096935	17565.4553	0.0000	0.0000
122.400	.714920	1279703.	31385.6407	-	0093066	19211.8327	0.0000	0.0000
126.000	.682144	1396015.	33258.8025	-	0088840	20957.9795	0.0000	0.0000
129.600	.650955	1519167.	35186.2589	-	0084236	22806.8300	0.0000	0.0000
133.200	.621494	1649356.	36297.2768	-	0081253	1215.2934	-17.6705	102.3562
136.800	.592453	1780507.	36296.5734	-	0080039	1311.9297	-74.6775	453.7726
140.400	.563866	1910691.	35917.1588	-	0078732	1407.8528	-136.1084	868.9833
144.000	.535766	2039111.	35312.1650	-	0077334	1502.4763	-199.9993	1343.8651
147.600	.508186	2164939.	34475.2911	-	0075845	1595.1899	-264.9307	1876.7747
151.200	.481157	2287333.	33405.9491	-	0074269	1685.3736	-329.1483	2462.6735
154.800	.454712	2405461.	32109.4550	-	0072608	1772.4141	-391.1262	3096.5846
158.400	.428880	2518521.	30594.3132	-	0070865	1855.7197	-450.6192	3782.4792
162.000	.403690	2625740.	28871.8330	-	0069044	1934.7222	-506.3142	4515.1809
165.600	.379169	2726398.	26958.9498	-	0067149	2008.8897	-556.3987	5282.7044
169.200	.355342	2819845.	24874.1730	-	0065185	2077.7440	-601.8106	6096.9873
172.800	.332235	2905492.	22629.8032	-	0063158	2140.8514	-645.0615	6989.6927
176.400	.309868	2982779.	20242.9813	-	0061074	2197.7989	-680.9507	7911.1745
180.000	.288262	3051242.	17741.8746	-	0058938	2248.2439	-708.5530	8848.8656
183.600	.267433	3110521.	15144.2498	-	0056756	2291.9226	-734.5719	9888.2981
187.200	.247397	3160280.	12467.6629	-	0054536	2328.5867	-752.4208	10948.8472
190.800	.228167	3200288.	9742.5366	-	0052285	2358.0657	-761.5382	12015.4905
194.400	.209752	3230426.	6991.6985	-	0050008	2380.2725	-766.7052	13159.0394
198.000	.192161	3250628.	4234.5157	-	0047714	2395.1578	-765.0630	14332.9068
201.600	.175398	3260915.	1500.9943	-	0045409	2402.7373	-753.5600	15466.5943
205.200	.159467	3261436.	-1184.1370	-	0043100	2403.1208	-738.1796	16664.5623
208.800	.144367	3252389.	-3819.9913	-	0040794	2396.4553	-726.1839	18108.4778
212.400	.130096	3233932.	-6396.7386	-	0038497	2382.8551	-705.3424	19518.2067
216.000	.116649	3206333.	-8882.5567	-	0036217	2362.5195	-675.6677	20852.3835
219.600	.104019	3169977.	-11246.0969	-	0033960	2335.7317	-637.4102	22060.1452
223.200	.092198	3125361.	-13457.4139	-	0031731	2302.8570	-591.0992	23080.4196
226.800	.081173	3073084.	-15489.0449	-	0029537	2264.3378	-537.5846	23841.8655
230.400	.070931	3013840.	-17370.5510	-	0027382	2220.6850	-507.6965	25767.4482
234.000	.061457	2948016.	-19163.4435	-	0025272	2172.1841	-488.3549	28606.4448
237.600	.052735	2875863.	-20879.6361	-	0023210	2119.0197	-465.0854	31749.2466
241.200	.044746	2797682.	-22505.3144	-	0021201	2061.4141	-438.0692	35244.2053
244.800	.037470	2713825.	-24027.4099	-	0019250	1999.6252	-407.5395	39154.6687
248.400	.030886	2624685.	-26285.0726	-	0017360	1933.9446	-346.7176	43869.6384
252.000	.024971	2524572.	-29281.6300	-	0015537	1860.1784	-318.0365	49017.934
255.600	.019699	2413857.	-32167.4997	-	0013789	1778.6005	-285.2245	54914.4497
259.200	.015043	2292966.	-34926.1792	-	0012123	1689.5243	-257.3752	61885.7
262.800	.010971	2162389.	-37536.8542	-	0010545	1593.3112	-232.9998	70060.8
266.400	.007450	2022701.	-39971.1290	-	0009064	1490.3849	-214.3751	79513.81
270.000	.004445	1874597.	-42185.0576	-	0007684	1381.2576	-199.5853	89820.9
273.600	.001918	1718968.	-44091.5847	-	0006412	1266.5860	-187.5964	101458.8
277.200	-.000172	1557137.	-44731.7184	-	0005252	1147.3442	-172.9666	114802.21
280.800	-.001864	1396900.	-43627.1577	-	0004206	1029.2767	-162.6783	129771.1
284.400	-.003200	1243022.	-41716.4783	-	0003272	915.8947	-154.8103	148212.5
288.000	-.004220	1096541.	-39570.5011	-	0002444	807.9636	-148.3993	173150.

Retaining Wall S - Pile and Lagging - 9.5 ft Wall Ht. lpo							
291.600	- .004960	958114.	-37269.1530	- .0001716	705.9665	657.1275	476988.
295.200	- .005455	828203.	-34856.3535	- .0001084	610.2444	683.3167	450926.
298.800	- .005740	707148.	-32361.8132	-5.4029E-05	521.0476	702.5391	440622.
302.400	- .005844	595198.	-29808.0200	-7.9242E-06	438.5595	716.2349	441189.
306.000	- .005797	492531.	-27213.2921	3.0583E-05	362.9110	725.2806	450408.
309.600	- .005624	399263.	-24593.3699	6.2154E-05	294.1884	730.2317	467422.
313.200	- .005349	315458.	-21962.3647	8.7456E-05	232.4390	731.4379	492230.
316.800	- .004994	241134.	-19333.3965	.0001072	177.6743	729.1001	525537.
320.400	- .004578	176258.	-16719.0875	.0001219	129.8720	723.2938	568786.
324.000	- .004116	120756.	-14132.0138	.0001325	88.9767	713.9694	624389.
327.600	- .003624	74507.4751	-11585.1969	.0001394	54.8993	700.9289	696235.
331.200	- .003113	37342.7854	-9092.7410	.0001433	27.5153	683.7688	790722.
334.800	- .002592	9039.7397	-6670.7813	.0001450	6.6607	661.7643	918997.
338.400	- .002069	-10686.8402	-4339.0829	.0001449	7.8744	633.6237	1102321.
342.000	- .001549	-22201.6569	-2124.1170	.0001437	16.3588	596.9129	1387269.
345.600	- .001034	-25980.4825	-66.1385	.0001420	19.1432	546.4085	1901729.
349.200	- .000526	-22677.8543	1758.4363	.0001403	16.7097	467.2442	3195834.
352.800	-2.41E-05	-13319.7412	2641.2393	.0001390	9.8144	23.2019	3467105.
356.400	.000475	-3660.9312	1849.9641	.0001384	2.6975	-462.7993	3509324.
360.000	.000973	0.0000	0.0000	.0001383	0.0000	-564.9585	1045496.

Output Veri fi cation:

Computed forces and moments are within speci fied convergence li mits.

Output Summary for Load Case No. 1:

Pile-head deflection = 2.19085664 in  
 Computed slope at pile head = -.01274363  
 Maximum bending moment = 3261436. lbs-in  
 Maximum shear force = -44731.71843 lbs  
 Depth of maximum bending moment = 205.20000 in  
 Depth of maximum shear force = 277.20000 in  
 Number of iterations = 20  
 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	2.1909	3261436.	-44731.7184

-----  
 Pile-head Deflection vs. Pile Length  
 -----

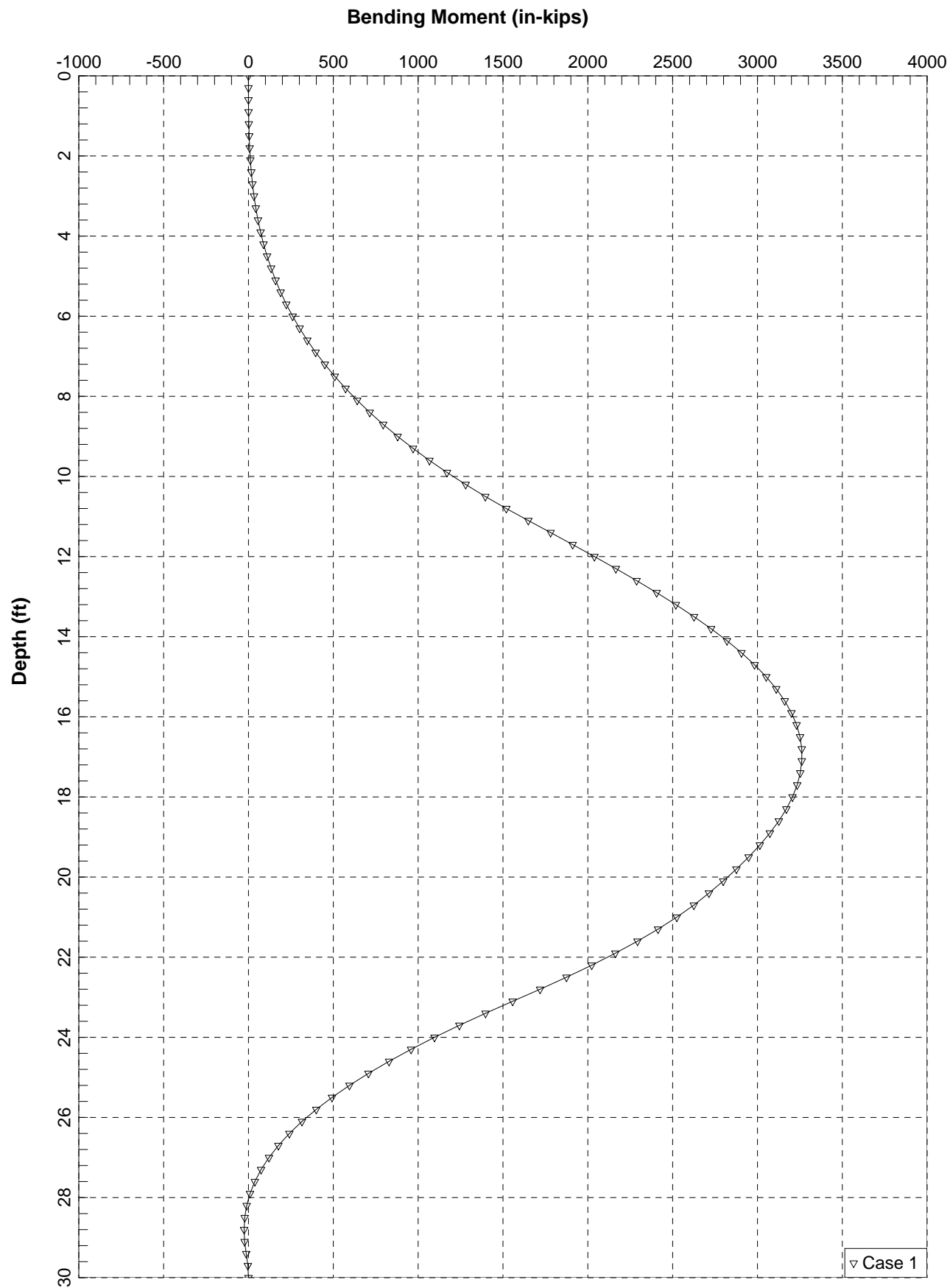
Boundary Condition Type 1, Shear and Moment

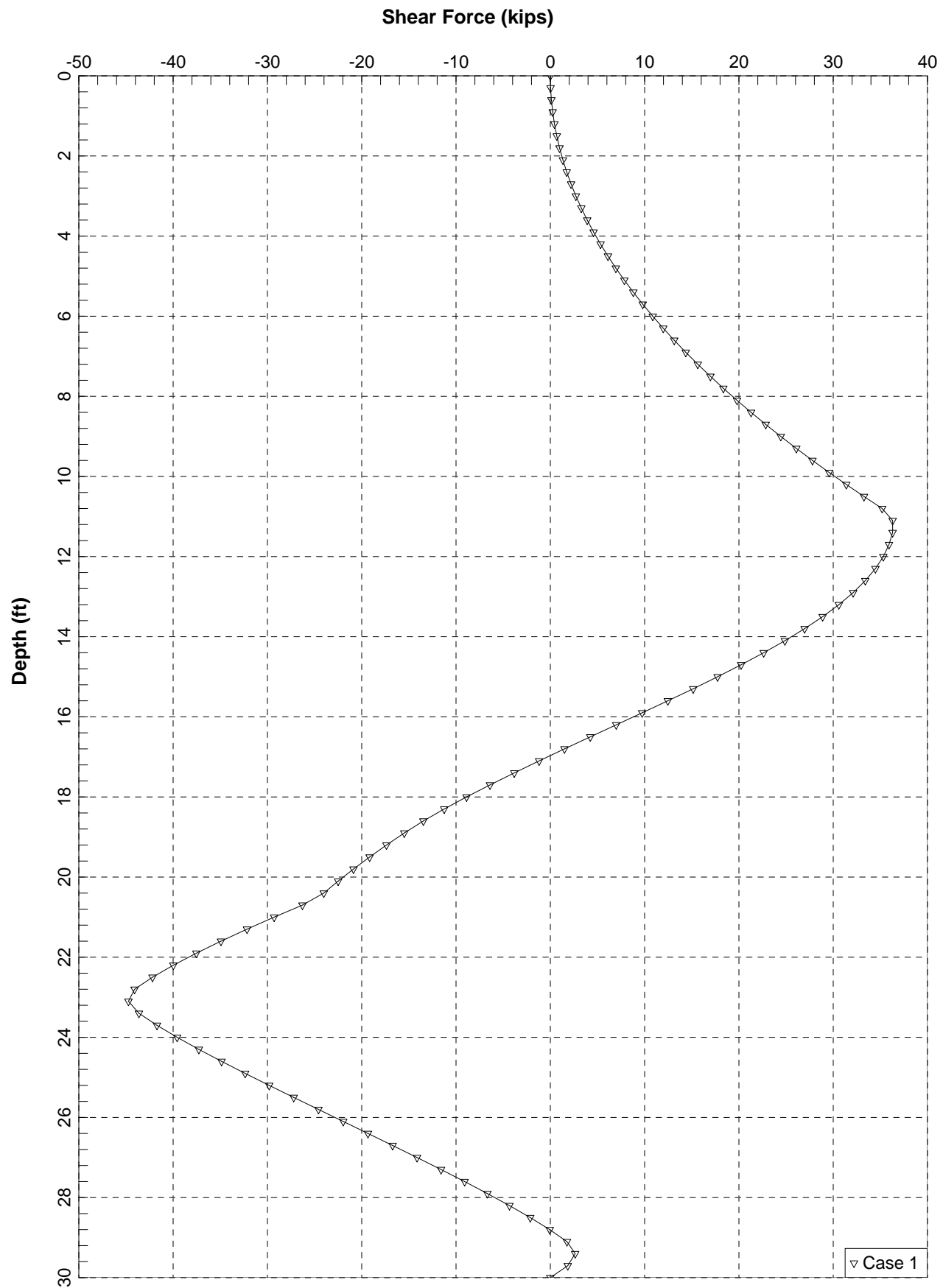
Shear = 0. lbs  
 Moment = 0. in-lbs  
 Axial Load = 0. lbs

Pile Length in	Pile Head Deflection in	Maximum Moment in-lbs	Maximum Shear lbs
360.000	2.19085664	3261436.	-44731.71843
342.000	2.19408573	3261941.	-45097.88597
324.000	2.29189866	3228728.	-49173.61927

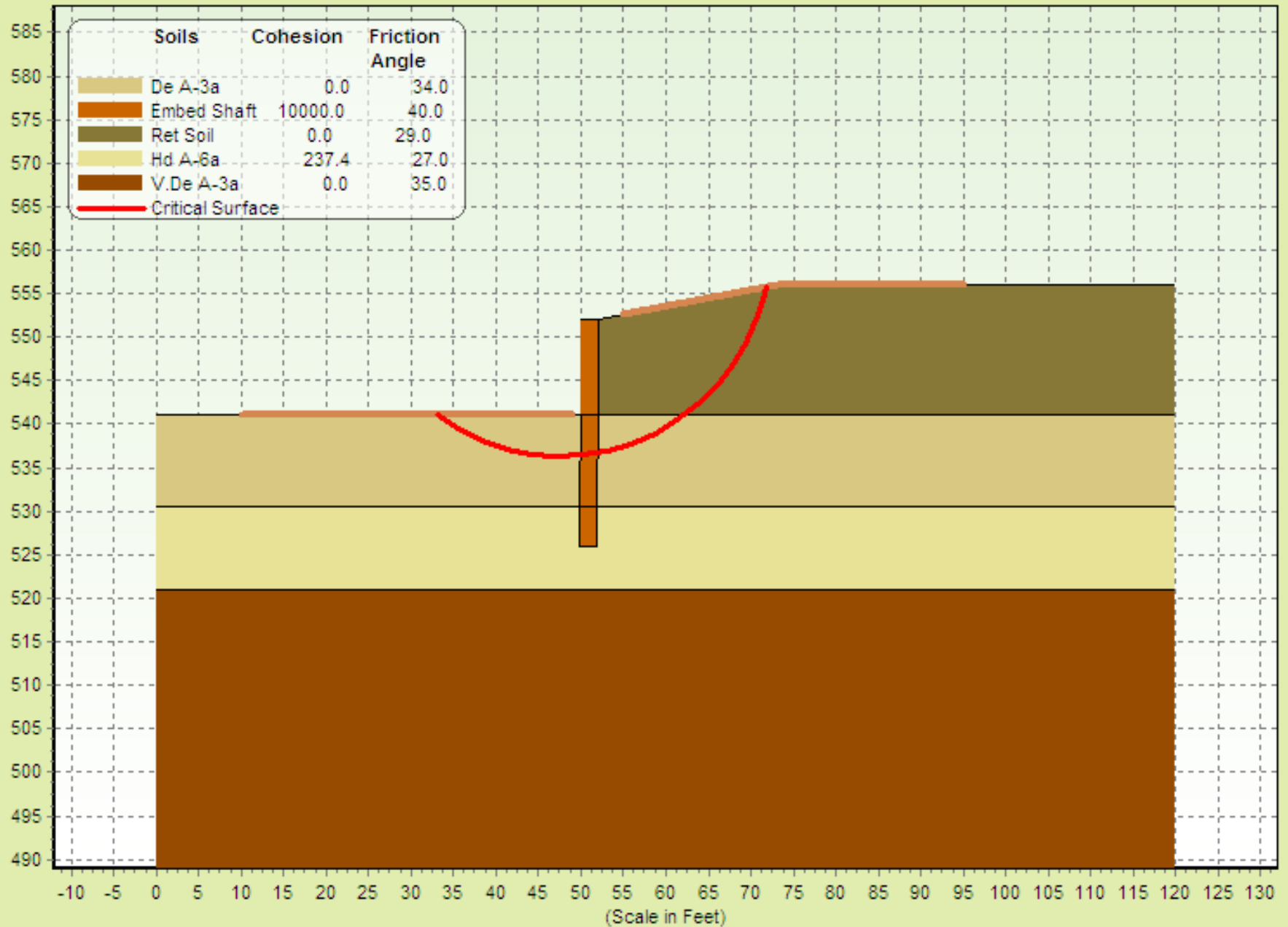
306.000	2.74198296	Retaining Wall S - Pile and Lagging - 9.5 ft Wall Ht. Ipo
288.000	3.85745743	3130510. -52131.36575
270.000	13.20799316	3009130. -53760.46406
		2995757. -66790.97294

The analysis ended normally.





Problem: B-10-020 - HAM-75-7.85 - Wall S - Sta. 446+40 - Pile and Lagging Wall - FS Min- Janbu = 2.871



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

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--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 S - Sta. 4  
 46+40 - Pile and Lagging Wall

BOUNDARY COORDINATES

5 Top Boundaries  
 17 Total Boundaries

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
**** ERROR - PF06 **** Boundaries 6 and 12					
1	0.00	541.00	50.00	541.00	2
2	50.00	541.00	50.10	552.00	5
3	50.10	552.00	52.10	552.00	5
4	52.10	552.00	73.00	556.00	1
5	73.00	556.00	120.00	556.00	1
6	50.00	541.00	52.00	541.00	5
7	52.00	541.00	52.10	552.00	1
8	52.00	541.00	120.00	541.00	2
9	0.00	530.50	49.90	530.50	3
10	49.90	530.50	50.00	541.00	5
11	49.90	530.50	51.90	530.50	5
12	51.90	530.50	52.00	541.20	2
13	51.90	530.50	120.00	530.50	3
14	49.80	526.00	49.90	530.50	5
15	49.80	526.00	51.80	526.00	3
16	51.80	526.00	51.90	530.50	3
17	0.00	521.00	120.00	521.00	4

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	130.0	0.0	29.0	0.00	0.0	1
2	130.0	135.0	0.0	34.0	0.00	0.0	1
3	125.0	135.0	237.4	27.0	0.00	0.0	1
4	135.0	140.0	0.0	35.0	0.00	0.0	1
5	140.0	140.0	10000.0	40.0	0.00	0.0	0

1

result.out

500 Trial Surfaces Have Been Generated.

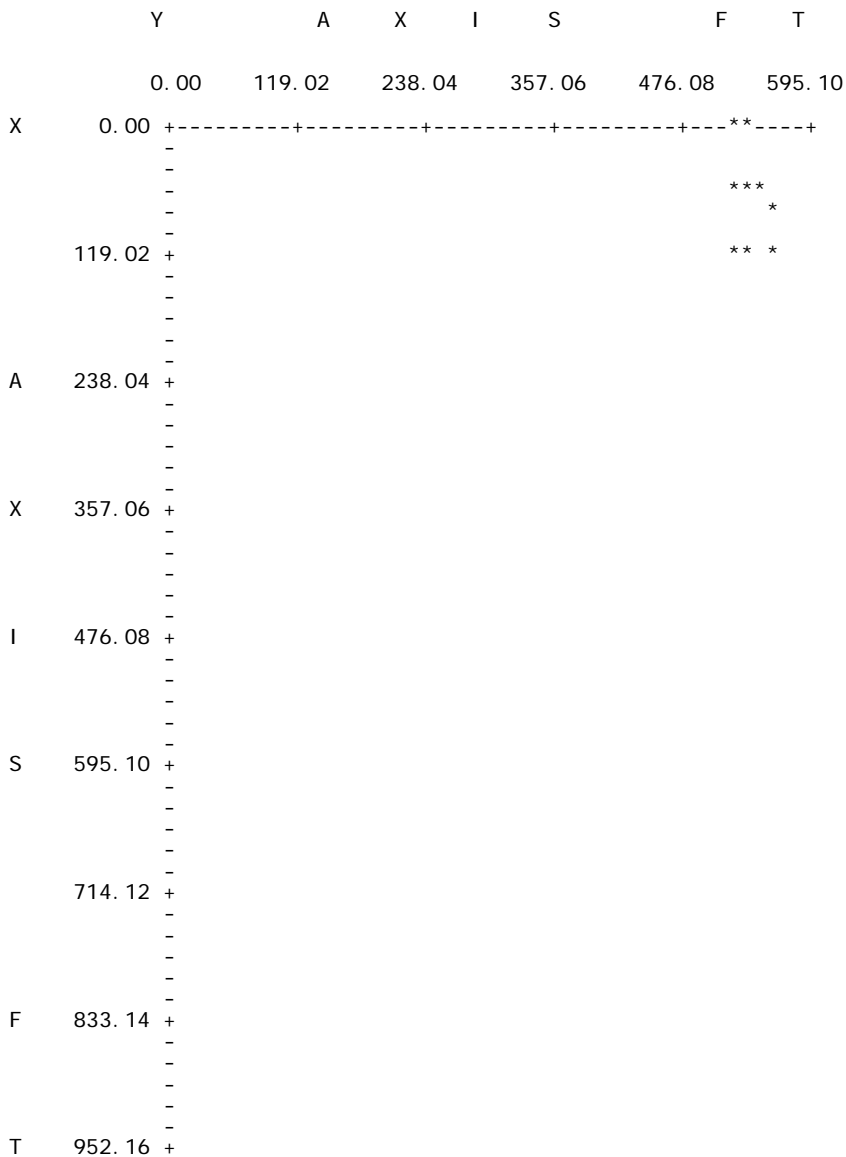
10 Surfaces Initiate From Each Of 50 Points Equally Spaced  
Along The Ground Surface Between X = 10.00 ft.  
and X = 49.00 ft.

Each Surface Terminates Between X = 55.00 ft.  
and X = 95.00 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



result.out

\*\*\*\*\*  
 \*\*\*\*\* EXECUTION OF STABL ABORTED \*\*\*\*\*  
 \*\*\*\*\*

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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 18 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	33.08	541.00
2	35.62	539.40
3	38.33	538.11
4	41.18	537.17
5	44.12	536.57
6	47.11	536.33
7	50.10	536.46
8	53.06	536.95
9	55.94	537.79
10	58.70	538.97
11	61.30	540.48
12	63.69	542.28
13	65.85	544.37
14	67.74	546.70
15	69.33	549.24
16	70.61	551.96
17	71.55	554.80
18	71.74	555.76

\*\*\* 2.871 \*\*\*

Individual data on the 24 slices

Slice No.	Width (ft)	Weight (lbs)	Water Force		Force Norm (lbs)	Force Tan (lbs)	Earthquake Force		Surcharge Load (lbs)
			Top (lbs)	Bot (lbs)			Hor (lbs)	Ver (lbs)	
1	2.5	264.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	2.7	791.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	2.8	1243.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	2.9	1579.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	3.0	1768.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	2.8	1706.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	26.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.1	140.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	9.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	1.9	3994.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	87.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.1	197.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	1.0	1802.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14	2.9	5320.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	2.8	4910.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	2.6	4326.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	0.7	1092.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18	1.7	2530.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	2.2	2873.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	1.9	2103.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	1.6	1373.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	1.3	738.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	0.9	253.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	0.2	10.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Failure Surface Specified By 17 Coordinate Points

result.out

Point No.	X-Surf (ft)	Y-Surf (ft)
1	35.47	541.00
2	37.89	539.23
3	40.54	537.82
4	43.35	536.78
5	46.29	536.15
6	49.28	535.94
7	52.27	536.14
8	55.21	536.76
9	58.03	537.78
10	60.68	539.18
11	63.11	540.94
12	65.27	543.02
13	67.12	545.38
14	68.63	547.98
15	69.75	550.76
16	70.48	553.67
17	70.69	555.56

\*\*\* 2.903 \*\*\*

1

Failure Surface Specified By 16 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	36.27	541.00
2	38.73	539.29
3	41.43	537.98
4	44.30	537.10
5	47.26	536.66
6	50.26	536.67
7	53.23	537.14
8	56.08	538.06
9	58.77	539.40
10	61.21	541.14
11	63.37	543.22
12	65.18	545.61
13	66.61	548.25
14	67.62	551.08
15	68.19	554.02
16	68.24	555.09

\*\*\* 2.905 \*\*\*

Failure Surface Specified By 19 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	33.08	541.00
2	35.43	539.13
3	37.99	537.56
4	40.72	536.32
5	43.58	535.42
6	46.53	534.88
7	49.52	534.70
8	52.52	534.89
9	55.47	535.45
10	58.33	536.36
11	61.05	537.61
12	63.60	539.19
13	65.94	541.07
14	68.03	543.22

result.out

15	69.84	545.61
16	71.35	548.21
17	72.53	550.97
18	73.36	553.85
19	73.70	556.00

\*\*\* 2.908 \*\*\*

1

Failure Surface Specified By 17 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	36.27	541.00
2	38.93	539.62
3	41.73	538.55
4	44.64	537.81
5	47.61	537.39
6	50.61	537.32
7	53.60	537.58
8	56.54	538.18
9	59.39	539.11
10	62.12	540.36
11	64.69	541.91
12	67.07	543.73
13	69.23	545.82
14	71.14	548.13
15	72.77	550.65
16	74.11	553.33
17	75.09	556.00

\*\*\* 2.916 \*\*\*

Failure Surface Specified By 19 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	33.88	541.00
2	36.53	539.59
3	39.31	538.47
4	42.19	537.63
5	45.14	537.09
6	48.13	536.86
7	51.13	536.94
8	54.11	537.33
9	57.03	538.02
10	59.86	539.01
11	62.58	540.28
12	65.15	541.82
13	67.55	543.62
14	69.75	545.66
15	71.73	547.91
16	73.47	550.35
17	74.95	552.96
18	76.16	555.71
19	76.25	556.00

\*\*\* 2.916 \*\*\*

1

Failure Surface Specified By 18 Coordinate Points

result.out

Poi nt No.	X-Surf (ft)	Y-Surf (ft)
1	34.67	541.00
2	37.00	539.10
3	39.56	537.55
4	42.32	536.37
5	45.22	535.58
6	48.19	535.22
7	51.19	535.27
8	54.16	535.74
9	57.02	536.62
10	59.74	537.90
11	62.25	539.54
12	64.50	541.52
13	66.46	543.80
14	68.07	546.33
15	69.32	549.06
16	70.17	551.93
17	70.61	554.90
18	70.62	555.54

\*\*\* 2.925 \*\*\*

Failure Surface Specified By 20 Coordinate Points

Poi nt No.	X-Surf (ft)	Y-Surf (ft)
1	28.31	541.00
2	30.86	539.43
3	33.56	538.12
4	36.38	537.10
5	39.29	536.35
6	42.25	535.90
7	45.25	535.75
8	48.25	535.91
9	51.21	536.35
10	54.12	537.10
11	56.94	538.13
12	59.64	539.44
13	62.19	541.01
14	64.58	542.83
15	66.77	544.87
16	68.75	547.13
17	70.49	549.57
18	71.98	552.18
19	73.20	554.92
20	73.56	556.00

\*\*\* 2.931 \*\*\*

1

Failure Surface Specified By 21 Coordinate Points

Poi nt No.	X-Surf (ft)	Y-Surf (ft)
1	27.51	541.00
2	30.07	539.43
3	32.76	538.11
4	35.57	537.05
5	38.46	536.26
6	41.42	535.75
7	44.41	535.52
8	47.41	535.58
9	50.39	535.93
10	53.32	536.55
11	56.18	537.46

result.out

12	58.95	538.63
13	61.58	540.05
14	64.07	541.73
15	66.40	543.63
16	68.52	545.74
17	70.44	548.05
18	72.13	550.52
19	73.58	553.15
20	74.77	555.91
21	74.80	556.00

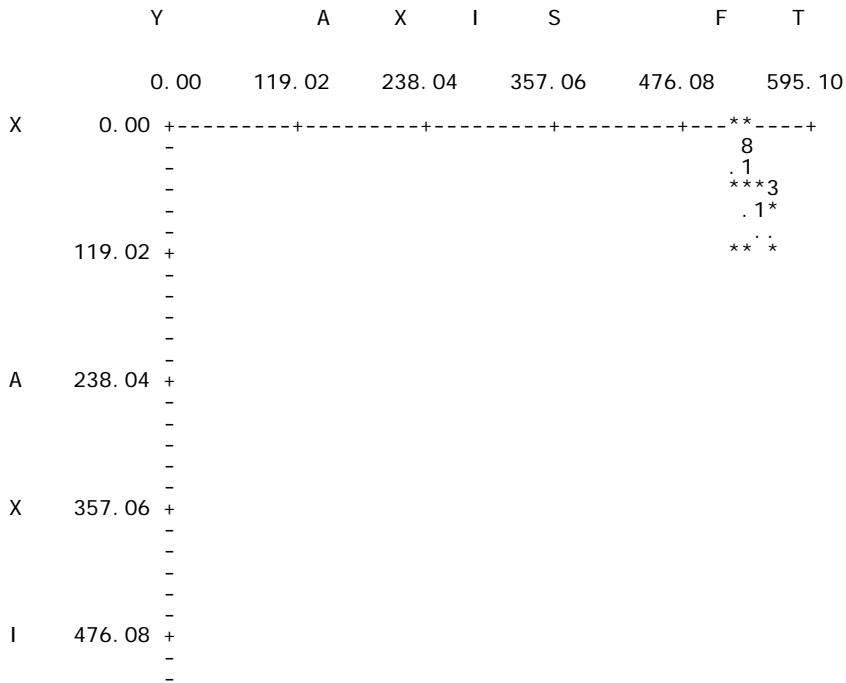
\*\*\* 2.936 \*\*\*

Failure Surface Specified By 16 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	38.65	541.00
2	41.39	539.76
3	44.25	538.88
4	47.21	538.38
5	50.21	538.26
6	53.20	538.53
7	56.13	539.18
8	58.95	540.21
9	61.61	541.58
10	64.08	543.29
11	66.31	545.30
12	68.26	547.58
13	69.90	550.09
14	71.20	552.79
15	72.15	555.64
16	72.19	555.84

\*\*\* 2.937 \*\*\*

1



result.out

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S 595.10 +  
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-  
-  
-  
714.12 +  
-  
-  
-  
F 833.14 +  
-  
-  
-  
-  
T 952.16 +
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