GANNETT FLEMING

MEMORANDUM

TO: Eric Holland, P.E.
FROM: Stephanie M. Chechak, P.E.
DATE: August 4, 2023
RE: SR88 Grade Crossing Site Improvement Project
Port Authority of Allegheny County
Contract No. R21-06-C, Work Order No. 6

For Design Purposes Only

INTRODUCTION

This memorandum presents the results of the subsurface exploration, geotechnical laboratory testing program, and geotechnical foundation evaluations completed in support of the SR 88 Grade Crossing Site Improvement Project. The proposed site improvements for the SR 88 Grade Crossing include the installation of four signalized gates, one on each side of the Light Rail Vehicle tracks for both northbound and southbound SR 88 traffic. This memorandum has been prepared in accordance with the scope of work approved under Contract No. R21-06-C, Work Order No. 6.

SITE DESCRIPTION

The site is located at the LRT Grade Crossing at SR 88, locally known as Library Road, in the municipality of Bethel Park, Allegheny County, PA. The site topography is relatively flat, with a ground surface elevation of approximately EL 991 on both sides of the tracks. The existing Grade Crossing includes light signals adjacent to the northbound and southbound lanes of Library Road.

SUBSURFACE INVESTIGATION

A site-specific geotechnical subsurface investigation program was performed in May 2022 and included two geotechnical test borings. As shown in Attachment 1, borings B-1 and B-2 were located adjacent to the northbound lane of Library Road on each side of the tracks. The Pennsylvania Drilling Company (Penn Drill) was procured to the test borings. Continuous soil sampling was performed with Standard Penetration Testing (SPT) using an 18” split-spoon sampler in accordance with ASTM International, Inc. (ASTM) Method D 1586. Bedrock coring was performed using wireline with a double tube, NQ-sized core barrel. Typed engineer boring logs were prepared and are included in Attachment 2.

SUBSURFACE CONDITIONS

The subsurface conditions encountered in B-1 and B-2 were relatively similar. Both test borings encountered loose to medium dense sand and gravel fill overlying soft to stiff alluvial clay, silt, and sand. Claystone of varying degrees of weathering was encountered below the alluvial soils. The claystone in boring B-1 was sampled as residual soil to a depth of 17 feet (EL 973.5), then cored to a depth of 29.6 feet (EL 960.9). A minimal amount of the claystone in boring B-2 was sampled as residual soil to a depth of 12.1 feet (EL 979.0), then cored to a depth of 27.5 feet (EL 963.6). Siltstone and limestone bedrock were present beneath the claystone.

Groundwater was encountered approximately 4 feet below the existing ground surface in both test borings.

LABORATORY TESTING

Laboratory testing was conducted to characterize the site soils, assess the site bedrock strength, and provide data to support the caisson foundation design. The laboratory testing was performed by Ackenheil Engineers, Inc. of Pittsburgh, PA. The tests that were conducted included soil classification, a soil corrosivity suite, and unconfined compressive strength testing of bedrock. Complete laboratory test results are included in Attachment 3.

GANNETT FLEMING

EVALUATIONS AND RECOMMENDATIONS

Foundation Design

A subsurface profile of the Grade Crossing was created using borings B-1 and B-2 (refer to Attachment 4). The caisson design model was created using the worst-case subsurface conditions encountered at the site. The conditions encountered in boring B-1 were considered worse than B-2, because the weathering of the claystone strata extended deeper, resulting in thicker residual soils. Refer to the calculation cover sheet in Attachment 4 for a detailed discussion of the subsurface material parameter selection.

Caisson foundations were evaluated for the proposed signal gates. Structural loadings at the base of the gate/top of caisson were provided by the Markosky Engineering Group (MEG). Two foundation evaluations were performed – one considering the caissons bearing in residual claystone and the second considering the caissons bearing in intact claystone. Based on the soft/loose nature of the site fill and alluvial soils, these strata were considered unsuitable bearing strata.

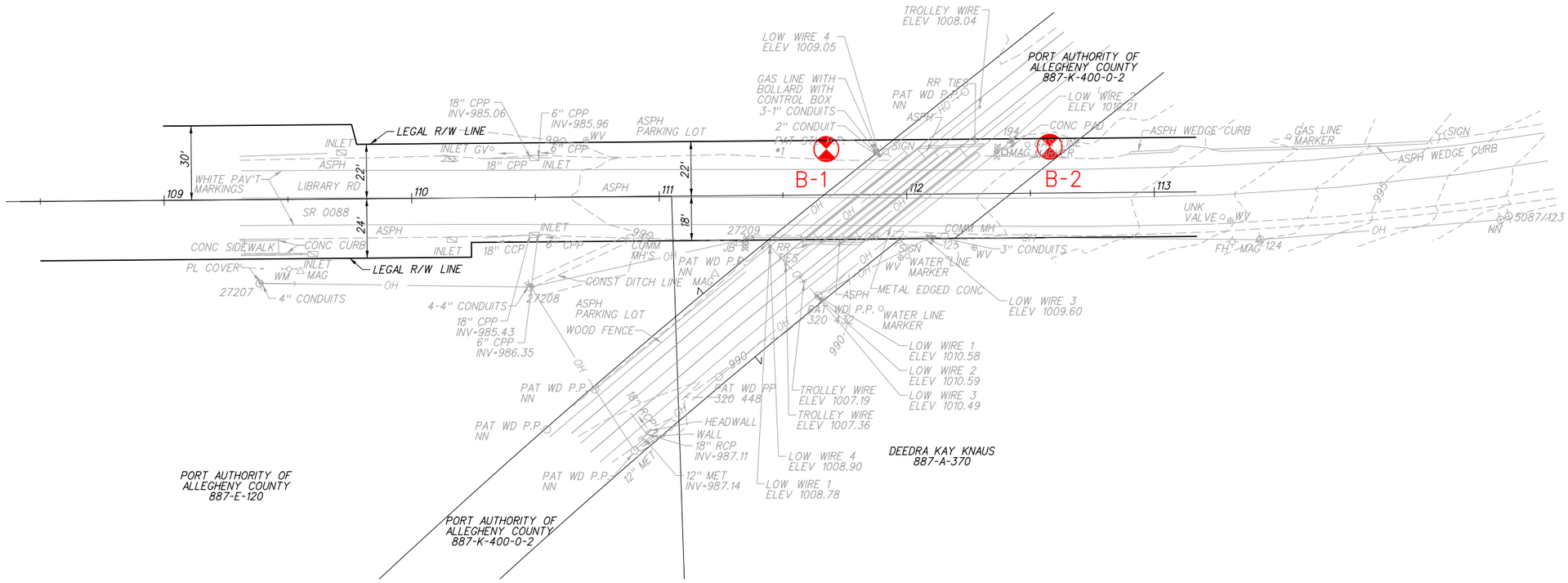
Based on the structural loadings provided, fixity of the caisson was the controlling design factor. A 16-foot-long caisson bearing 4.5 feet within the residual claystone was unable to achieve fixity (refer to the bending moment versus depth graphs for caissons in residual soil in Attachment 4). A 20-foot-long caisson with a 3-foot-long socket into intact claystone was able to achieve fixity (refer to the bending moment versus depth graphs for caissons in intact claystone in Attachment 4). The 20-foot-long caisson also achieves minimal deflection at the SER-I (0.05 inches) and STR-I (0.03 inches) loading cases. These deflections are within the allowable tolerances of 0.5 inches and 1.0 inch, respectively. Additionally, the intact claystone bearing stratum provides sufficient bearing resistance at the caisson tip (factored resistance = 16 kips > STR-1 axial load = 1.91 kips and unfactored resistance = 33 kips > SER-I axial load = 1.53 kips).

The following recommendations are made based on the results of the geotechnical foundation analyses for the proposed signal gates:

- Socket the caissons a minimum of 3 feet into intact claystone
- Caisson Diameter = 2 feet
- Total Caisson Length = 20 feet
- Minimum Caisson Tip Elevation = EL 970.5
- Bearing Resistance Factor: $\varphi_{qp} = 0.5$
- Geological Strength Index (GSI) = 40
- Constant $m_i = 5$

ATTACHMENT 1

BORING LOCATION PLAN



PRELIMINARY

NO.	DATE	DESCRIPTION

REVISIONS

Gannett Fleming

GANNETT FLEMING, INC.
Foster Plaza 8
Suite 400
730 Holiday Drive
Pittsburgh, PA. 15220

SIGNATURE

APPROVED DATE

DESIGNED	
DRAWN	
CHECKED	
IN CHARGE	
DATE FEBRUARY 2022	
SCALE AS NOTED	

PORT AUTHORITY OF ALLEGHENY COUNTY
PITTSBURGH, PENNSYLVANIA

RT 88 GRADE CROSSING
SITE IMPROVEMENT PROJECT

Port Authority

CONTRACT NO. XXX-22-XX

DWG. NO. | SHT.

FILE: pw:\\gfnet-pw.bentley.com:gfnet-pw-01\Documents\Projects\62984_037\OUTPUT\COMP_01\CIVIL\GEOTYPLOT\Rt 88 Grade Crossing - Boring Plan.dgn
DATE: 2/24/2022 TIME: 12:27:08 PM

ATTACHMENT 2

ENGINEER'S BORING LOGS

pennsylvania
DEPARTMENT OF TRANSPORTATION

ENGINEER'S LOG

Boring **B-1** ECMS

District: 11 County: Allegheny
SR 88 Section 20
Baseline: SR88
Sta. Offset
Segment 990-1100 Offset
Coordinates:
Lat. Long.
1332551.1138 E 358410.3381 N
Ground Elev. 990.5 ft.
Water Level Elev./Elapsed Time:
▽ Initial 986.7 ft. Elapsed 0.0 hr.
▼ Final 985.9 ft. Elapsed 21.0 hr.
Driller: Justin Greenslate
Company: Pennsylvania Drilling Company

Drilling Start: 05/24/2022 9:00 am
Drilling Complete: 05/24/2022 12:00 pm
Grouting Complete: 05/25/2022 9:30 am
Rig: Acker Soil Max Track Rig
Hammer Type: Automatic
SPT Hammer Efficiency:
Assumed 0.8 Measured
Hammer Calibration Date:
Hole Type: Continuous SPT - Rock Core
Casing Type: Hollow Stem Auger
Casing I.D.: 3.25 in Casing Depth: 17.0 ft.
Rock Core Method: Double Tube Wire Line-NQ
Inspector: Kaitlin DeOre
Inspector Cert. No. 510-22

PG/PE Seal, Signature and Date

Final Log Checked and Approved
By:
Date:

NOTE: N values and all graphical plots are for information only.

ELEV.	GRAPHIC	MATERIAL DESCRIPTION COMMENTS - OBSERVATIONS	AASHTO / USCS	SAMPLE DEPTH	SAMPLE No.	BLOW COUNTS (Blows/ 0.5ft)	N_{60} --- RQD %	REC (ft.)	REC (%)
990		**GRAVEL**, some Sand, some Silt, loose to medium dense, damp, heterogeneous, angular, non-plastic, dark brown and light brown, fill, *colors also include gray and black, trace pavement millings*.	a-2-5 / gm	1.5	S-1	6-16-9	33	1.5	100
				3.0	S-2	6-10-5	20	0.8	53
		S-3 and S-4: Low recovery, soft material but no tool drops.		4.5	S-3	3-2-2	5	0.4	27
		5.0'/El. 985.5			S-4	4-2-1	4	0.5	33
985		**CLAY**, little Silt, little Sand, trace Gravel, soft to stiff, damp to wet, heterogeneous, sub-angular, dark brown and red brown, alluvium, *low to medium plastic fines, colors also include light brown, sand content increase with depth*. *5.0': Wet*. *S-5: No recovery, outside of spoon wet with clay residue. Replaced broken catcher*.	a-6 / cl	6.0	S-5	WOH-WOH-3	4	0.0	0
				7.5	S-6	1-3-4 **Pen=1.00 tsf**	9	1.3	87
		S-7: More sand content in spoon.		9.0	S-7	6-5-6 **Pen=1.00 tsf**	15	1.5	100
980		*10.0': Wet*.		10.5	S-8	3-5-14 **Pen=0.50 tsf**	25	1.5	100
		11.5'/El. 979.0							
		Weathered CLAYSTONE, very dense, moist to wet, non-plastic, light gray, residuum.		12.0	S-9	25-48-50	131	1.5	100
				13.5	S-10	26-20-50/.3'	93	1.3	100
				14.8					

◇ RQD % ◇
⊙ Soil/Rock Rec.% ⊙ (20 40 60 80)
▲ SPT (N_{60}) ▲ (10 20 30 40)

NOTE: OFFSET BORING 5' OFF SHOULDER DUE TO MARKED GAS LINE

PENNDOT ENGINEER'S LOG - PENNDOT_GINT_VERSION_1.2.2.3_9-21-2016.GDT - 5/25/22 14:23 - C:\USERS\KDEORE\ONEDRIVE - GANNETT FLEMING INC\DESKTOP\SR88 GATE CROSSING.GPJ

pennsylvania
DEPARTMENT OF TRANSPORTATION

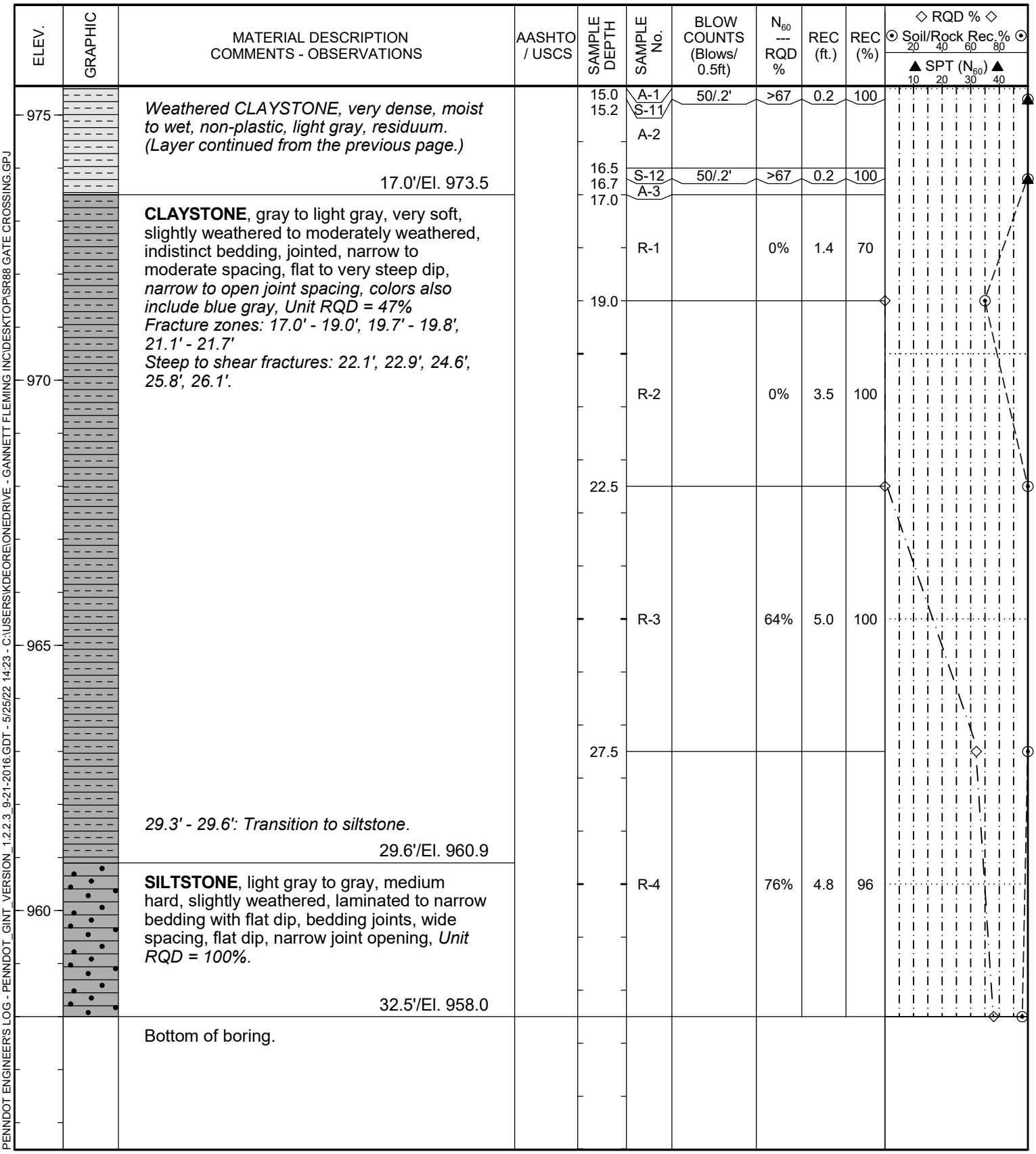
ENGINEER'S LOG

Boring **B-1** ECMS _____ District: 11 County: Allegheny

SR 88 Section 20

Sta. _____ Offset _____

NOTE: N values and all graphical plots are for information only.



PENNDOT ENGINEER'S LOG - PENNDOT_GINT_VERSION_1.2.2.3_9-21-2016.GDT - 5/25/22 14:23 - C:\USERS\KDEORE\ONEDRIVE - GANNETT FLEMING INC\DESKTOP\SR88 GATE CROSSING.GPJ

NOTE: OFFSET BORING 5' OFF SHOULDER DUE TO MARKED GAS LINE

pennsylvania
DEPARTMENT OF TRANSPORTATION

ENGINEER'S LOG

Boring **B-2** ECMS

District: 11 County: Allegheny
SR 88 Section 20
Baseline: SR88
Sta. Offset
Segment 990-1100 Offset
Coordinates:
Lat. Long.
1332607.3393 E 358502.6196 N
Ground Elev. 991.1 ft.
Water Level Elev./Elapsed Time:
▽ Initial 987.6 ft. Elapsed 0.0 hr.
▼ Final 987.1 ft. Elapsed 19.5 hr.
Driller: Justin Greenslate
Company: Pennsylvania Drilling Company

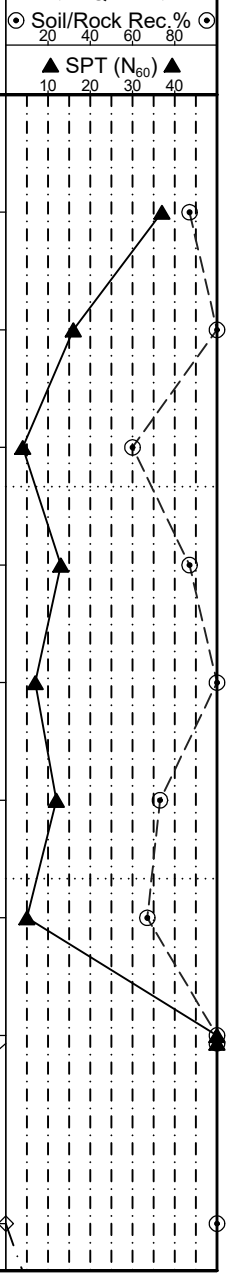
Drilling Start: 05/24/2022 12:30 pm
Drilling Complete: 05/24/2022 2:00 pm
Grouting Complete: 05/25/2022 10:00 am
Rig: Acker Soil Max Track Rig
Hammer Type: Automatic
SPT Hammer Efficiency:
Assumed 0.8 Measured
Hammer Calibration Date:
Hole Type: Continuous SPT - Rock Core
Casing Type: Hollow Stem Auger
Casing I.D.: 3.25 in Casing Depth: 12.1 ft.
Rock Core Method: Double Tube Wire Line-NQ
Inspector: Kaitlin DeOre
Inspector Cert. No. 510-22

PG/PE Seal, Signature and Date

Final Log Checked and Approved
By:
Date:

NOTE: N values and all graphical plots are for information only.

ELEV.	GRAPHIC	MATERIAL DESCRIPTION COMMENTS - OBSERVATIONS	AASHTO / USCS	SAMPLE DEPTH	SAMPLE No.	BLOW COUNTS (Blows/ 0.5ft)	N_{60} --- RQD %	REC (ft.)	REC (%)
990		**GRAVEL**, some Sand, some Silt, medium dense, damp, heterogeneous, sub-angular, non-plastic, dark brown and brown, fill, *colors also include gray*. 2.0'/El. 989.1	a-2-5 / gm	1.5	S-1	6-19-9	37	1.3	87
					S-2	7-6-6	16	1.5	100
		CLAY, some Sand, little Silt, little Gravel, soft to stiff, damp to wet, heterogeneous, sub-rounded, dark brown and brown, alluvium, *low to medium plastic fines, colors also include black and red brown, some clay mottled throughout, sand pockets throughout and generally increased with depth*.		3.0	S-3	WOH-1-2 **Pen=1.50 tsf**	4	0.9	60
				4.5	S-4	2-3-7 **Pen=0.50 tsf**	13	1.3	87
985			a-6 / cl	6.0	S-5	4-3-2 **Pen=1.00 tsf**	7	1.5	100
				7.5	S-6	5-4-5 **Pen=0.50 tsf**	12	1.1	73
				9.0	S-7	WOH-WOH-4 **Pen=1.00 tsf**	5	1.0	67
		11.0'/El. 980.1		10.5					
980		*Weathered CLAYSTONE, very dense, damp, light gray, red brown, residuum.* 12.1'/El. 979.0		12.0	S-8	5-16-42	77	1.5	100
				12.1	S-9	50/.1'	>67	0.1	100
					R-1		0%	2.3	100
				14.4					



PENNDOT ENGINEER'S LOG - PENNDOT_GINT_VERSION_1.2.2.3_9-21-2016.GDT - 5/25/22 14:24 - C:\USERS\KDEORE\ONEDRIVE - GANNETT FLEMING INC\DESKTOP\SR88 GATE CROSSING.GPJ

pennsylvania
DEPARTMENT OF TRANSPORTATION

ENGINEER'S LOG

Boring **B-2** ECMS _____ District: 11 County: Allegheny

SR 88 Section 20

Sta. _____ Offset _____

NOTE: N values and all graphical plots are for information only.

ELEV.	GRAPHIC	MATERIAL DESCRIPTION COMMENTS - OBSERVATIONS	AASHTO / USCS	SAMPLE DEPTH	SAMPLE No.	BLOW COUNTS (Blows/ 0.5ft)	N_{60} --- RQD %	REC (ft.)	REC (%)	◇ RQD % ◇ ⊙ Soil/Rock Rec.% ⊙ 20 40 60 80 ▲ SPT (N_{60}) ▲ 10 20 30 40
975		**CLAYSTONE**, light gray to dark gray, very soft, slightly weathered to moderately weathered, indistinct bedding, jointed, narrow to moderate spacing, flat to steep dip, open joints, *colors also include blue gray, Unit RQD = 48%* *Fracture zones: 14.5' - 14.6', 17.5' - 17.7', 17.9' - 19.1', 22.2' - 22.3'* *Possible sandstone seams: 13.1' - 13.3', 14.3' - 14.7'* *Siltstone seams: 12.1' - 14.0'.* *(Layer continued from the previous page.)*			R-2		46%	3.5	100	
				17.9						
970					R-3		55%	5.1	100	
				23.0						
965		*25.8' - 27.5': Transition to siltstone*.			R-4		59%	5.1	100	
		27.5'/El. 963.6								
		SILTSTONE, light gray to gray, medium hard, slightly weathered to weathered, thin bedding with flat dip, bedding joints, close spacing, flat to shallow dip, narrow joint opening, *Unit RQD = 0%*.								
		28.1'/El. 963.0								
960		Bottom of boring.								

PENNDOT ENGINEER'S LOG - PENNDOT_GINT_VERSION_1.2.2.3_9-21-2016.GDT - 5/25/22 14:24 - C:\USERS\KDEORE\ONEDRIVE - GANNETT FLEMING INC\DESKTOP\SR88 GATE CROSSING.GPJ

ATTACHMENT 3

GEOTECHNICAL LABORATORY TESTING RESULTS

LABORATORY TEST REQUISITION

Geotechnical Lab Manager

Date Submitted

Date Required:

Date Returned

Laboratory: Ackenheil Engineers, Inc.

Project Name: SR88 Gate Crossing | County: Allegheny | Municipality: Bethel Park

Project Number: 062984 - WO37 | S.R.: 88 | ~~Segment~~/Section

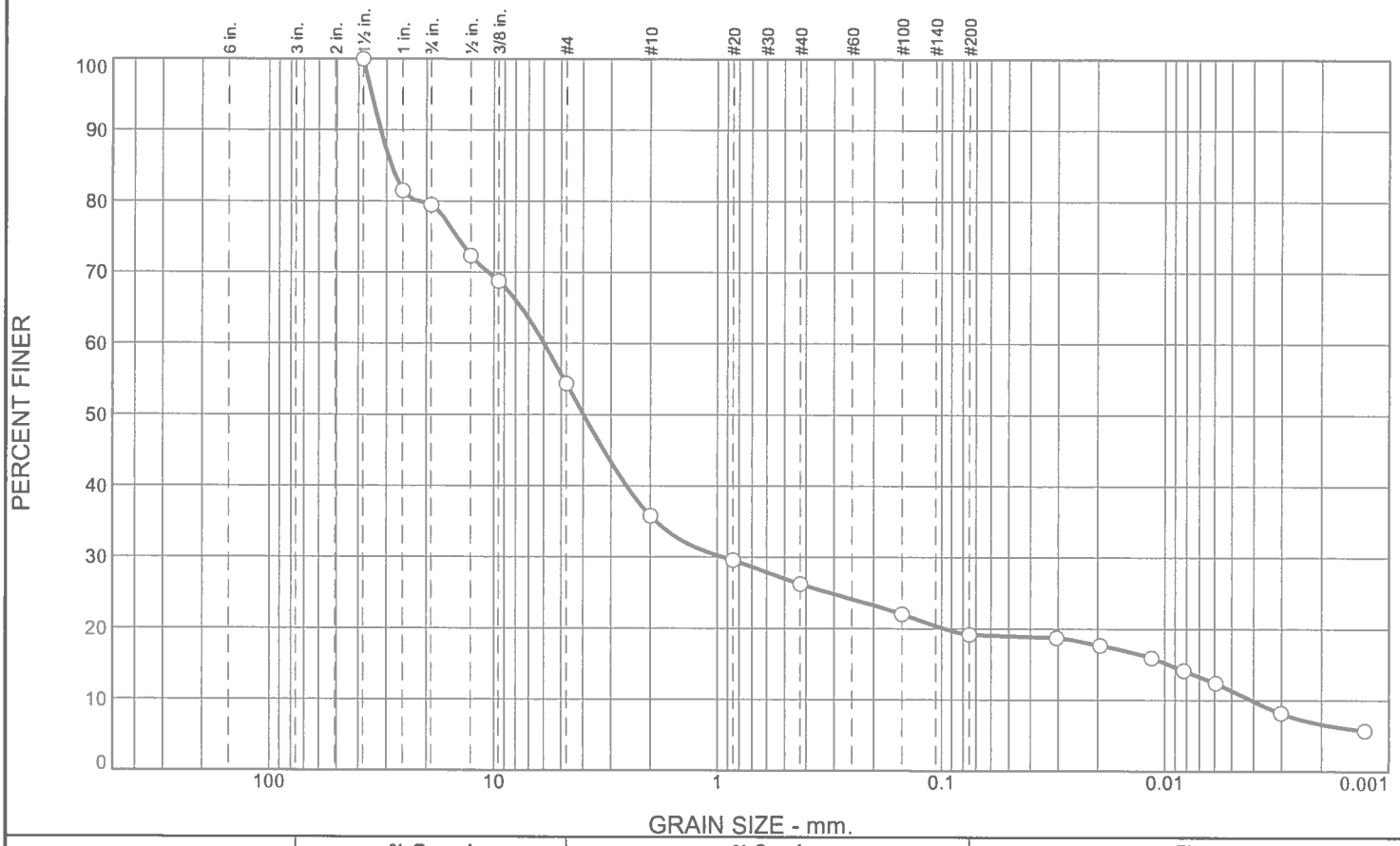
Project Manager/Engineer: Holland, Eric | Geotechnical Engineer: Brian Heinzl, P.E. | Phone: (412) 215-9484

TEST BORING/PIT NUMBER	SAMPLE NUMBER	SAMPLE DEPTH FROM	SAMPLE DEPTH TO	NUMBER AND SAMPLE TYPES [1] SHELBY	ROCK CORE	JAR	BAG	WATER	LAB NUMBER YEAR	NO.	SAMPLE ID NO.	NUMBER AND TYPE OF TESTS REQUIRED: Soil Classification (ASTM D2487) [2]	Moisture Content (AASHTO T-265/ASTM D2216)	Soil Corrosivity (T288, T289, T290, T291)	Unconfined Compressive Strength - Rock (ASTM D2938)					COMPLETED	REMARKS [3]
B-1	S-1,2,3	3.0	4.5			3						1									
B-1	R-4	31.2	32.0		3										1						Select representative core from sample interval
B-2	S-3	3.0	4.5			1								1							
B-2	S-4,5,6	4.5	9.0			3						1									
TOTAL NUMBER OF TESTS												0	0	1	1	0	0	0	0		TOTAL COST FOR
UNIT COST (ESTIMATE)												$130.00	$10.00	$310.00	$130.00						ALL TESTS:
TOTAL COST												$260.00	$0.00	$310.00	$130.00	$0.00	$0.00	$0.00	$0.00		$670.00

[1] **Combine all bags, jars, and runs for each sample set into one representative sample.**

[2] **Includes Soil Identification (D2488), Sieve Analysis (D422), Atterberg Limits (T-89)(Hydrometer if applicable), and Moisture Content.**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	20.5	25.1	18.6	9.5	7.1	7.8	11.4

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1 1/2	100.0		
1	81.5		
3/4	79.5		
1/2	72.3		
3/8	68.8		
#4	54.4		
#10	35.8		
#20	29.6		
#40	26.3		
#100	22.1		
#200	19.2		
0.0305 mm.	18.7		
0.0195 mm.	17.7		
0.0115 mm.	15.9		
0.0082 mm.	14.2		
0.0059 mm.	12.4		
0.0030 mm.	8.2		
0.0013 mm.	5.7		

* (no specification provided)

Soil Description

silty gravel with sand

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{90}= 31.8539 D_{85}= 28.5297 D_{60}= 5.9876
D_{50}= 3.9853 D_{30}= 0.9388 D_{15}= 0.0096
D_{10}= 0.0041 C_u= 1468.72 C_c= 36.11

Classification

USCS= GM AASHTO= A-1-b

Remarks

Moisture Content: 9.9%

Source of Sample: B-1 **Depth:** 0.0' - 4.5'
Sample Number: S-1,2,3

Date: 7/5/22

ACKENHEIL ENGINEERS, INC.

Pittsburgh, PA

Client: Gannett Fleming
Project: SR 88 Gate Crossing

Project No: 20303 (062984 - WO37) **Figure**

Tested By: DAR **Checked By:** JTL

ACKENHEIL ENGINEERS, INC.
GEOTECHNICAL · CIVIL · INSPECTION · TESTING
1000 Banksville Road, Pittsburgh, Pennsylvania 15216
Ph 412-531-7111 · Fax 412-531-4334 · www.ackenheil.com

ROCK UNCONFINED COMPRESSION TEST- ASTM D 7012 (METHOD C)

PROJECT INFORMATION

Project:	SR 88 Gate Crossing	AE Project No.:	20303
Client:	Gannett Fleming	Report Date:	7/5/2022

SAMPLE DATA

Specimen Boring No.	B-1
Specimen Boring Run	R-4
Specimen Depth	31.2 - 32.0 ft
Specimen Description	
Specimen Tested Date	7/5/2022
Specimen Moisture, Room Temperature (At Test)	Moist, 68°F
Specimen End Preparation Method	Saw-Cut
Length	4.25 in
Diameter	1.96 in
Aspect Ratio [Length(L) to Diameter(D)]	2.16
ASTM D7012 Dimensional Requirements Conformance	Yes

TEST RESULTS

Load At Failure	4,610 lbs
Load Rate	1,537 lbs/min
Unit Weight	158.0 pcf
Unconfined Compressive Strength	**1,524 psi**

REMARKS

Note: Specimen Dimensional requirements were not checked according to ASTM D4543 and results may differ from specimens meeting such requirements

PICTURE OF FAILURE SURFACE



ACKENHEIL ENGINEERS, INC.
GEOTECHNICAL · CIVIL · INSPECTION · TESTING
1000 Banksville Road, Pittsburgh, Pennsylvania 15216
Ph 412-531-7111 · Fax 412-531-4334 · www.ackenheil.com

CORROSIVITY TEST RESULTS

Project:	SR 88 Gate Crossing
Project No.:	20303
Client:	Gannett Fleming
Date:	7/5/2022

Matrix: Soil						
Location	**Sample No.**	**Depth**	**Minimum Resistivity (Ohm-cm)** **AASHTO T288**	**pH** **AASHTO T-289**	**Sulfate (ppm)** **AASHTO T-290**	**Chloride (ppm)** **AASHTO T-291**
B-2	S-3,4,5	3.0' - 7.5'	2,900	6.7	244	587

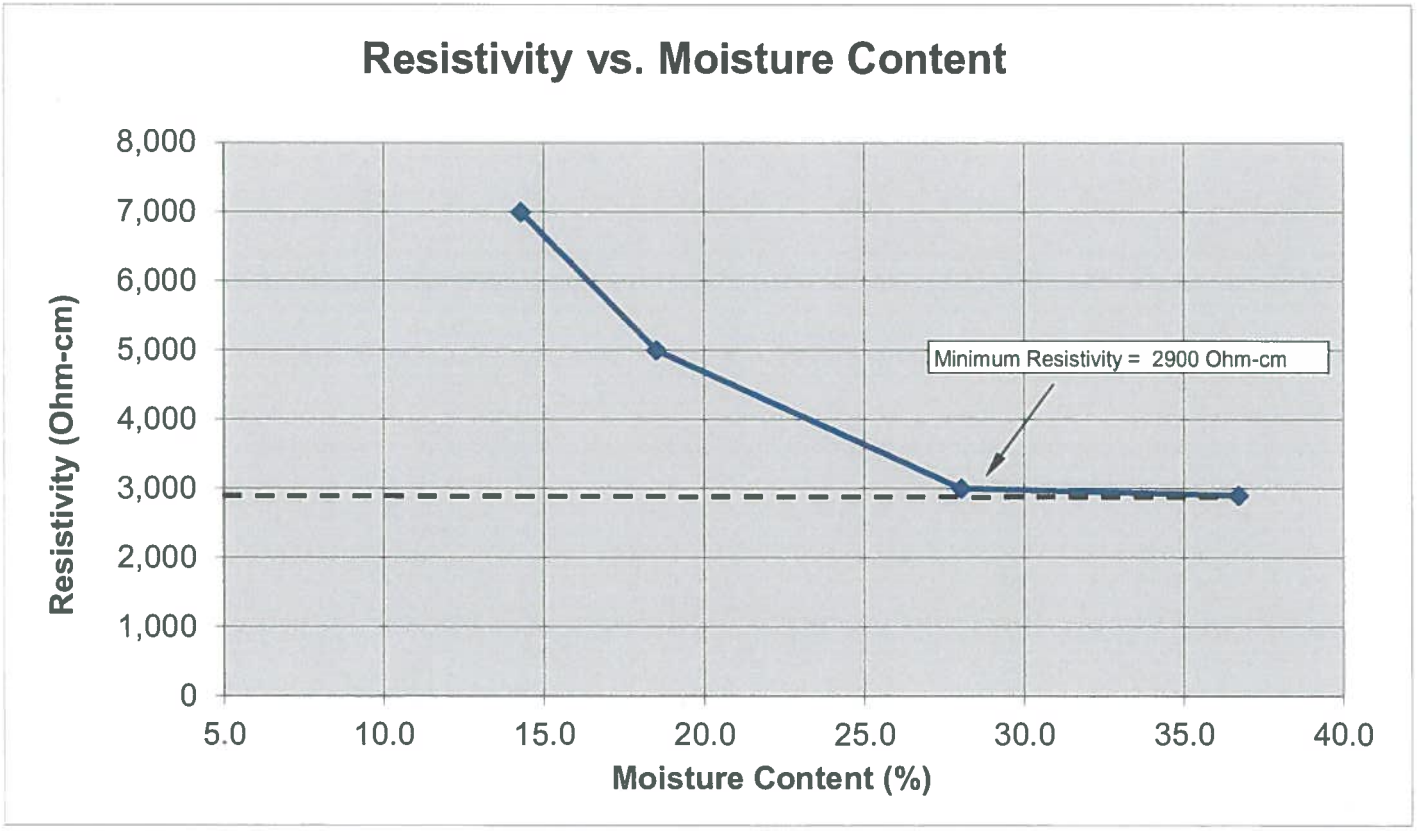
ACKENHEIL ENGINEERS, INC.
GEOTECHNICAL · CIVIL · INSPECTION · TESTING
1000 Banksville Road, Pittsburgh, Pennsylvania 15216
Ph 412-531-7111 · Fax 412-531-4334 · www.ackenheil.com

SOIL RESISTIVITY TEST REPORT (AASHTO T 288)

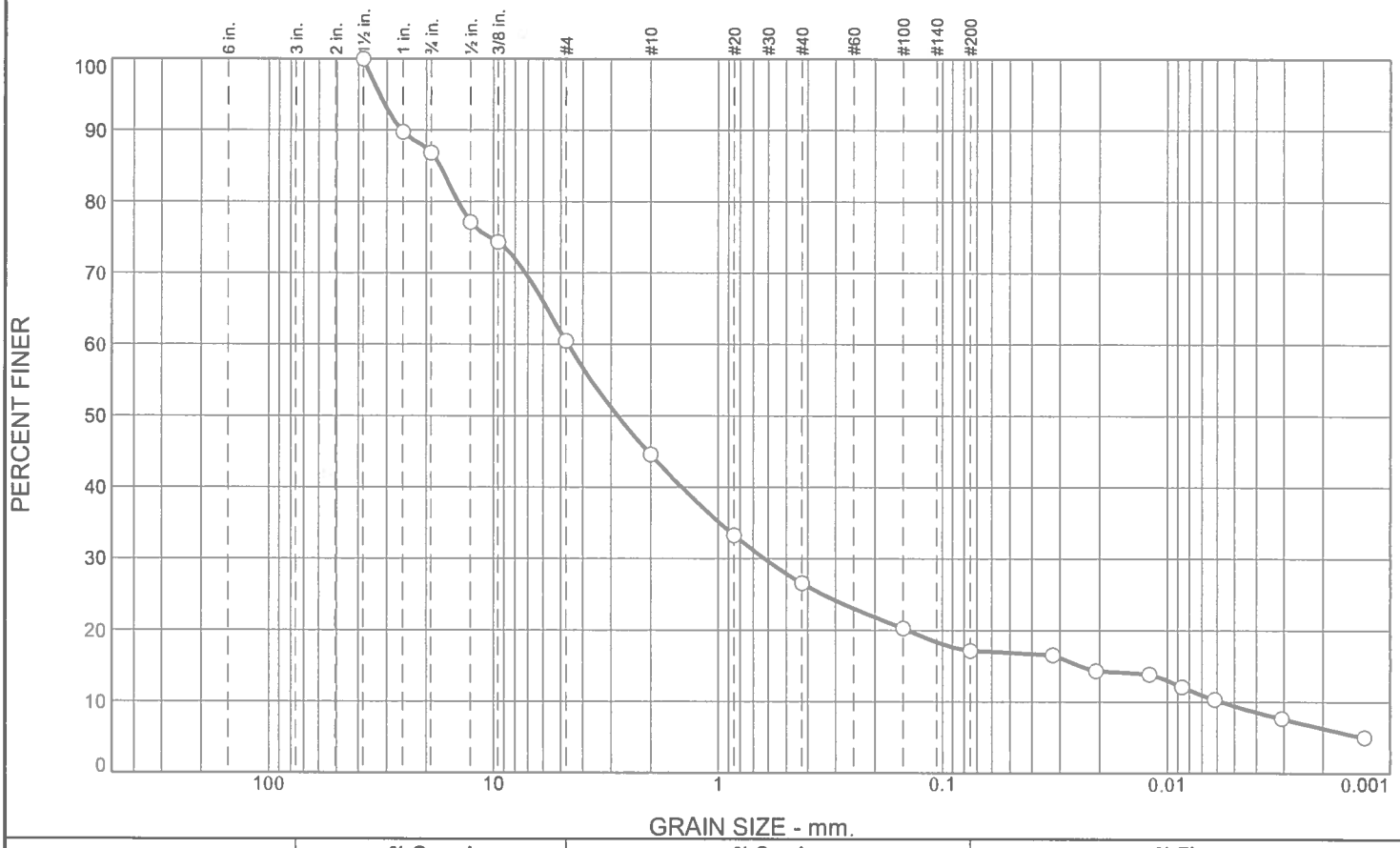
PROJECT INFORMATION		SAMPLE INFORMATION	
Project Name:	SR 88 Gate Crossing	Boring Location:	B-2
Project Number:	20303	Sample Number:	S-3,4,5
A.E. Client:	Gannett Fleming	Sample Interval (ft)	3.0 - 7.5
Date of Test:	7/5/2022	Sample Type:	Jar Samples

SOIL BOX DATA		RESISTIVITY TEST DATA				
Box Length (cm):	22.23	Moisture Content (%)	Measured Resistance (ohms)	Box Factor	Soil Resistivity (Ohm-cm)	% Change
Box Area (cm^2):	12.56					
Electrode Spacing (cm):	12.56					
Box Factor (Area/Spacing):	1.00	14.3	7,000	1	7,000	NA
Box Volume (cm^3):	279.21	18.5	5,000	1	5,000	29%
Box Weight (gm):	189.42	28.0	3,000	1	3,000	40%
		36.7	2,900	1	2,900	3%

MINIMUM RESISTIVITY TEST RESULTS		SOIL CLASSIFICATION INFORMATION	
Moisture Content:	28.0%	USCS Group Name:	
Minimum Resistivity (Ohm-cm):	2,900	USCS / AASHTO:	M.C.:



Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	13.2	26.3	15.9	18.0	9.4	7.8	9.4

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1 1/2	100.0		
1	89.7		
3/4	86.8		
1/2	77.1		
3/8	74.3		
#4	60.5		
#10	44.6		
#20	33.3		
#40	26.6		
#100	20.3		
#200	17.2		
0.0323 mm.	16.5		
0.0207 mm.	14.3		
0.0120 mm.	13.9		
0.0086 mm.	12.1		
0.0062 mm.	10.3		
0.0031 mm.	7.7		
0.0013 mm.	5.0		

* (no specification provided)

Soil Description

silty sand with gravel

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{90}= 25.8704 D_{85}= 17.4103 D_{60}= 4.6533
D_{50}= 2.8030 D_{30}= 0.6238 D_{15}= 0.0243
D_{10}= 0.0057 C_u= 811.88 C_c= 14.59

Classification

USCS= SM AASHTO= A-1-b

Remarks

Moisture Content: 22.3%

Source of Sample: B-2 **Depth:** 4.5' - 9.0'
Sample Number: S-4,5,6

Date: 7/5/22

ACKENHEIL ENGINEERS, INC.

Pittsburgh, PA

Client: Gannett Fleming
Project: SR 88 Gate Crossing

Project No: 20303 (062984 - WO37) **Figure**

Tested By: DAR **Checked By:** JTL

ATTACHMENT 4

GATE FOUNDATION DESIGN

GANNETT FLEMING

Subject: SR 88 Grade Crossing Caisson Foundation Design | Sheet of | Job No. 073937.06
By SMC Date 7/23 | Chkd. RHY Date 8/23

OBJECTIVE: To design a drilled shaft foundations for the proposed SR88 grade crossing gates.

METHODOLOGY:

- Borings B-1 and B-2 were used in the creation of the subsurface model. Both borings included loose alluvial sand and gravel, little clay overlying residual claystone and intact claystone.
    - The subsurface conditions encountered in B-1 were slightly worse than B-2; as a result, the subsurface model was based on B-1 (see attached).

- Subsurface materials consist of:
    - 0.0' – 11.5': Loose Fill/Alluvial Sand and Gravel, little Clay (see attached Bowles table for parameter selection).
    - 11.5' – 17.0': Dense to very dense residual claystone (see attached Bowles table for parameter selection).
    - 17.0' – 30.0': Intact Claystone (see attached Hoek and Bray, AASHTO, and DM-4 pages for parameter selection).
    - Groundwater table EL 987.0

- Loads were provided by structural engineers from The Markosky Engineering Group (see attached) as follows:

    - SER-I Load Case:
        - Axial = 1,530.60 lb
        - Shear = 1,551.23 lb
        - Moment = 13,961.06 ft*lb = 167,532.72 in*lb

    - STR-I Load Case:
        - Axial = 1,913.25 lb
        - No wind load, and as a result, no shear and moment, included for the STR-I case.

- A maximum 2-foot diameter caisson was considered for the gate foundations based on the gate size requirements and existing utility locations at the project site.

- Two caisson bearing strata were considered for the proposed foundation. The first includes a 16-foot-long caisson bearing within residual soil. A 16-foot-long caisson allows for 4.5 of bearing within residual soil. The second bearing strata includes a 20-foot-long caisson bearing within intact claystone. A 20-foot-long caisson allows for a 3-foot socket into the intact claystone.

METHODOLOGY (continued):

For caissons bearing within residual soil:

- The LPILE analyses were performed considering the following proposed caisson foundation specifications:
  - Caisson Diameter = 2 ft.
  - Caisson Length = 16 ft. (EL 991 to EL 975)
  - Caisson Stick-up = 0 ft. (Top of caisson to be flush to the ground)
  - Embedment into Residual Soil = 4.5 ft.

- Deflections calculated at the top of the caisson are as follows:
  - SER-I Load Case: $\delta = 0.06$ inches < 0.5 inches
  - STR-I Load Case: $\delta = 0.04$ inches < 1.0 inches

- The anticipated deflections for both the service and strength cases are minimal and fall within the 0.5 inch and 1.0 inch requirements for the service and strength cases, respectively.

- An assessment of the moment diagram for the caissons in residual soil, the moment graph crosses the 0 in*lb line at the very bottom of the graph.

- The residual soil was evaluated to determine the bearing resistance of the strata versus the anticipated axial loading (see attached spreadsheet).

- An unfactored tip resistance of 188 kips and a factored tip resistance of 94 kips were calculated for a caisson bearing 4.5 feet into the residual soil. Axial loads of 1.53 kips and 1.91 kips were calculated for the service and strength loading cases, respectively.

For caissons bearing within intact claystone:

- The LPILE analyses were performed considering the following proposed caisson foundation specifications:
  - Caisson Diameter = 2 ft.
  - Caisson Length = 20 ft. (EL 991 to EL 971)
  - Caisson Stick-up = 0 ft. (Top of caisson to be flush to the ground)
  - Embedment into Intact Claystone = 3 ft.

- Deflections calculated at the top of the caisson are as follows:
  - SER-I Load Case: $\delta = 0.05$ inches < 0.5 inches
  - STR-I Load Case: $\delta = 0.03$ inches < 1.0 inches

METHODOLOGY (continued):

For caissons bearing within intact claystone:

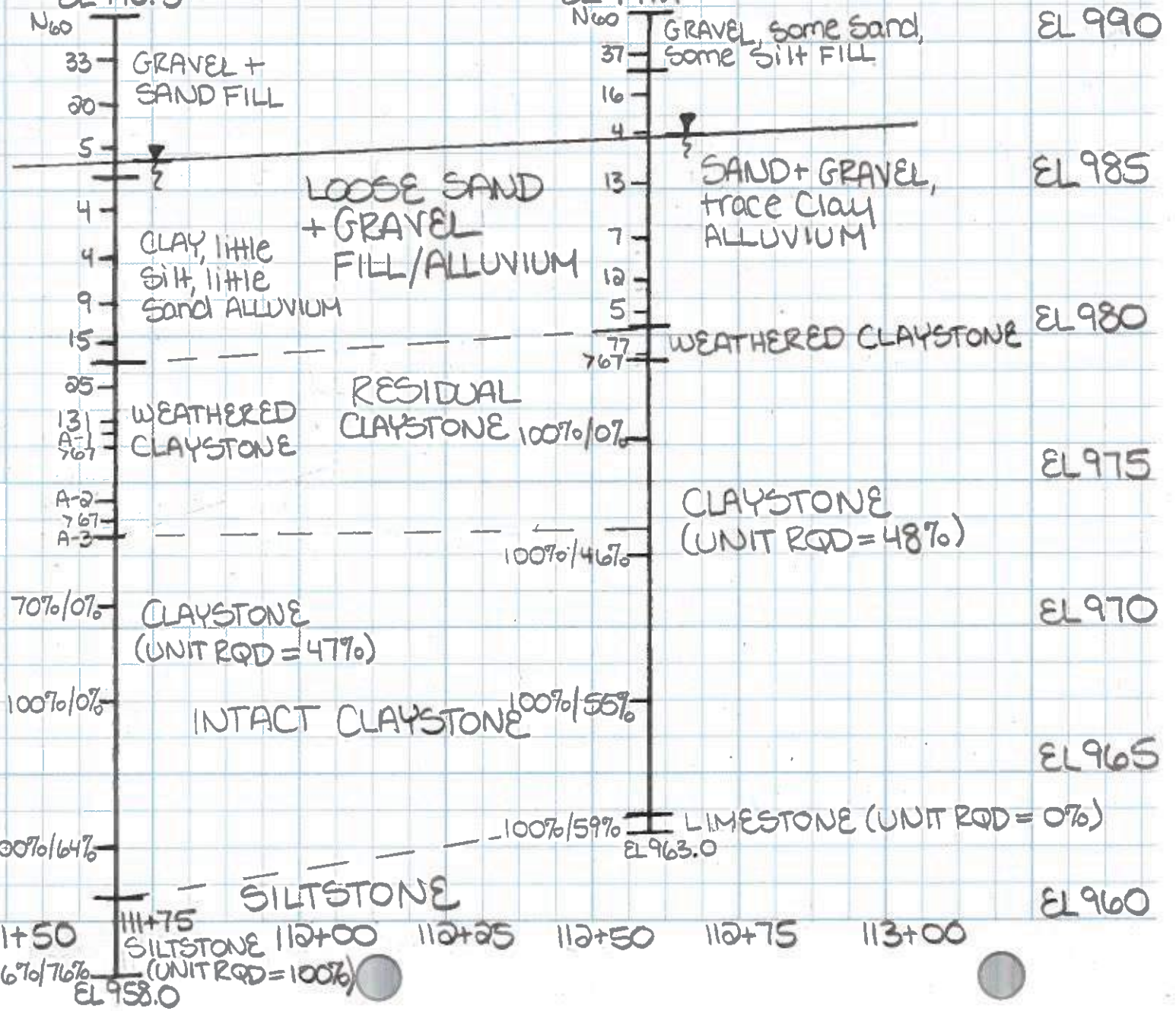
- The anticipated deflections for both the service and strength cases are minimal and fall within the 0.5 inch and 1.0 inch requirements for the service and strength cases, respectively.

- The intact portion of the claystone was evaluated to determine the bearing resistance of the strata versus the anticipated axial loading (see attached spreadsheet).

- An unfactored tip resistance of 33 kips and a factored tip resistance of 16 kips were calculated for a caisson bearing 3 feet into the intact claystone. Axial loads of 1.53 kips and 1.91 kips were calculated for the service and strength loading cases, respectively. As a result, the intact claystone strata provides sufficient tip resistance to support a 20-foot-long caisson.

SUBJECT Route 88 Grade Crossing Site Improvement Project SHEET NO. 1 OF 1
BY SMC DATE 1/23 CHKD. BY DATE JOB NO. 073937.00
Gannett Fleming

SR 88 GRADE CROSSING SUBSURFACE PROFILE



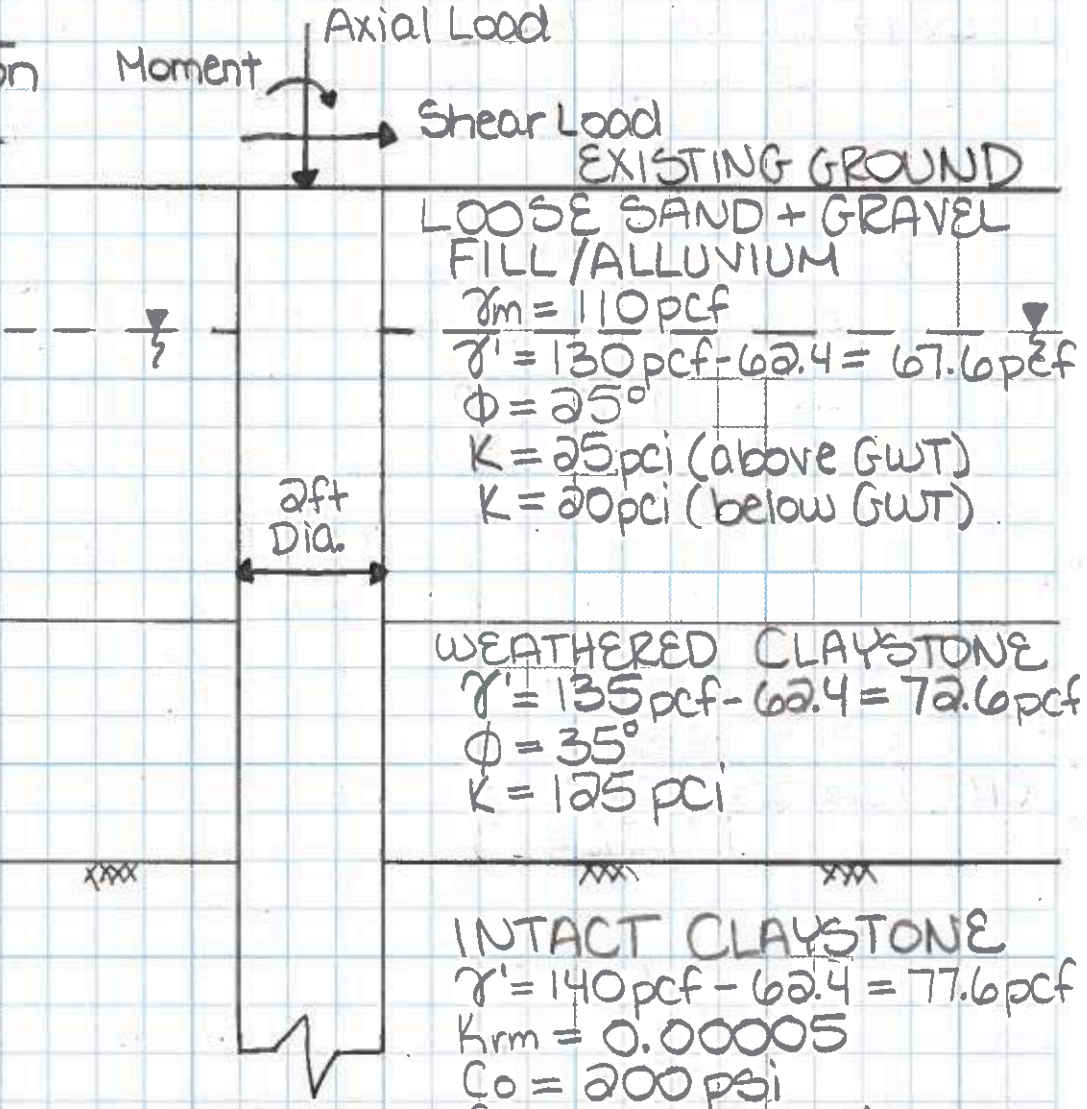
Gannett Fleming

SUBJECT Route 88 Grade Crossing Site Improvement Project SHEET NO. OF JOB NO. 073931.06

BY SMC DATE 7/23 CHKD. BY DATE

LPILE Model

Depth (ft)	Elevation (ft)
0	991.0
4.0	987.0
11.5	979.0
17.0	973.5
30.0	961.0



SER-I Load Case

⇒ Shear = 1,551.23 lb
⇒ Axial = 1,530.60
⇒ Moment = 13,961.06 ft·lb
= 167,532.72 in·lb

STR-I Load Case

⇒ Axial = 1,913.25

SER-I Load Case Results
Caisson Bearing in Residual Soil

```
================================================================================

                    LPile for Windows, Version 2022-12.009

                 Analysis of Individual Piles and Drilled Shafts
               Subjected to Lateral Loading Using the p-y Method
                          © 1985-2022 by Ensoft, Inc.
                              All Rights Reserved

================================================================================
```

By: SMC 07/23
Checked by: RHY 08/23

```
This copy of LPile is being used by:

Gannett Fleming, Inc
Pittsburgh, PA


Serial Number of Security Device: 546957815

This copy of LPile is licensed for exclusive use by:

Gannett Fleming, Inc., LPILE Sm Global, SmGlobal Licens

Use of this software by employees of Gannett Fleming, Inc.
other than those of the office site in LPILE Sm Global, SmGlobal Licens
is a violation of the software license agreement.

--------------------------------------------------------------------------------
                              Files Used for Analysis
--------------------------------------------------------------------------------

Path to file locations:
\Users\schechak\Desktop\SR88 Grade Crossing\

Name of input data file:
SR88 Grade Crossing Caisson (SER-I Load Case) (Caisson Bearing in Residual
Soil).lp12d

Name of output report file:
SR88 Grade Crossing Caisson (SER-I Load Case) (Caisson Bearing in Residual
Soil).lp12o

Name of plot output file:
SR88 Grade Crossing Caisson (SER-I Load Case) (Caisson Bearing in Residual
Soil).lp12p

Name of runtime message file:
SR88 Grade Crossing Caisson (SER-I Load Case) (Caisson Bearing in Residual
Soil).lp12r
```

Date and Time of Analysis

Date: July 28, 2023 Time: 14:44:17

Problem Title

Project Name: SR88 Grade Crossing Gate Foundation

Job Number: 073937.06

Client: Port Authority of Allegheny County

Engineer: S. Chechak

Description:

Program Options and Settings

Computational Options:
- Conventional Analysis

Engineering Units Used for Data Input and Computations:
- US Customary System Units (pounds, feet, inches)

Analysis Control Options:

- Maximum number of iterations allowed	=	500
- Deflection tolerance for convergence	=	1.0000E-05 in
- Maximum allowable deflection	=	100.0000 in

```
 - Number of pile increments                              =          100

Loading Type and Number of Cycles of Loading:
 - Static loading specified

 - Use of p-y modification factors for p-y curves not selected
 - Analysis uses layering correction (Method of Georgiadis)
 - No distributed lateral loads are entered
 - Loading by lateral soil movements acting on pile not selected
 - Input of shear resistance at the pile tip not selected
 - Input of moment resistance at the pile tip not selected
 - Computation of pile-head foundation stiffness matrix not selected
 - Push-over analysis of pile not selected
 - Buckling analysis of pile not selected

Output Options:
 - Output files use decimal points to denote decimal symbols.
 - Values of pile-head deflection, bending moment, shear force, and
   soil reaction are printed for full length of pile.
 - Printing Increment (nodal spacing of output points) = 1
 - No p-y curves to be computed and reported for user-specified depths
 - Print using wide report formats




---------------------------------------------------------------------------
                     Pile Structural Properties and Geometry
---------------------------------------------------------------------------

Number of pile sections defined                          =            1
Total length of pile                                     =       16.000 ft
Depth of ground surface below top of pile                =       0.0000 ft

Pile diameters used for p-y curve computations are defined using 2 points.

p-y curves are computed using pile diameter values interpolated with depth over
the length of the pile. A summary of values of pile diameter vs. depth follows.

            Depth Below           Pile
Point        Pile Head          Diameter
 No.            feet              inches
-----      -------------     -------------
  1             0.000           24.0000
  2            16.000           24.0000


Input Structural Properties for Pile Sections:
----------------------------------------------
```

Pile Section No. 1:

Section 1 is a round drilled shaft, bored pile, or CIDH pile

Length of section	=	16.000000 ft
Shaft Diameter	=	24.000000 in

Soil and Rock Layering Information

The soil profile is modelled using 4 layers

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

Distance from top of pile to top of layer	=	0.0000 ft
Distance from top of pile to bottom of layer	=	4.000000 ft
Effective unit weight at top of layer	=	110.000000 pcf
Effective unit weight at bottom of layer	=	110.000000 pcf
Friction angle at top of layer	=	25.000000 deg.
Friction angle at bottom of layer	=	25.000000 deg.
Subgrade k at top of layer	=	25.000000 pci
Subgrade k at bottom of layer	=	25.000000 pci

Layer 2 is sand, p-y criteria by Reese et al., 1974

Distance from top of pile to top of layer	=	4.000000 ft
Distance from top of pile to bottom of layer	=	11.500000 ft
Effective unit weight at top of layer	=	67.600000 pcf
Effective unit weight at bottom of layer	=	67.600000 pcf
Friction angle at top of layer	=	25.000000 deg.
Friction angle at bottom of layer	=	25.000000 deg.
Subgrade k at top of layer	=	20.000000 pci
Subgrade k at bottom of layer	=	20.000000 pci

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

Distance from top of pile to top of layer	=	11.500000 ft
Distance from top of pile to bottom of layer	=	17.000000 ft
Effective unit weight at top of layer	=	72.600000 pcf
Effective unit weight at bottom of layer	=	72.600000 pcf
Friction angle at top of layer	=	35.000000 deg.
Friction angle at bottom of layer	=	35.000000 deg.
Subgrade k at top of layer	=	125.000000 pci
Subgrade k at bottom of layer	=	125.000000 pci

Layer 4 is weak rock, p-y criteria by Reese, 1997

Distance from top of pile to top of layer	=	17.000000 ft
Distance from top of pile to bottom of layer	=	30.000000 ft
Effective unit weight at top of layer	=	77.600000 pcf
Effective unit weight at bottom of layer	=	77.600000 pcf
Uniaxial compressive strength at top of layer	=	200.000000 psi
Uniaxial compressive strength at bottom of layer	=	200.000000 psi
Initial modulus of rock at top of layer	=	1420000. psi
Initial modulus of rock at bottom of layer	=	1420000. psi
RQD of rock at top of layer	=	51.000000 %
RQD of rock at bottom of layer	=	51.000000 %
k rm of rock at top of layer	=	0.0000500
k rm of rock at bottom of layer	=	0.0000500

(Depth of the lowest soil layer extends 14.000 ft below the pile tip)

Summary of Input Soil Properties

Layer Num.	Soil Type Name or (p-y Curve Type)	Layer Depth ft	Effective Unit Wt. pcf	Angle of Friction deg.	Uniaxial qu psi	RQD %	E50 or kpy Modulus Rock Mass krm pci psi
1	Sand	0.00	110.0000	25.0000	--	--	25.0000 --
	(Reese, et al.)	4.0000	110.0000	25.0000	--	--	25.0000 --
2	Sand	4.0000	67.6000	25.0000	--	--	20.0000 --
	(Reese, et al.)	11.5000	67.6000	25.0000	--	--	20.0000 --
3	Sand	11.5000	72.6000	35.0000	--	--	125.0000 --
	(Reese, et al.)	17.0000	72.6000	35.0000	--	--	125.0000 --
4	Weak	17.0000	77.6000	--	200.0000	51.0000	5.00E-05 -- 1420000.
	Rock	30.0000	77.6000	--	200.0000	51.0000	5.00E-05 -- 1420000.

Static Loading Type

Static loading criteria were used when computing p-y curves for all analyses.

Pile-head Loading and Pile-head Fixity Conditions

Number of loads specified = 1

Load No.	Load Type	Condition 1	Condition 2	Axial Thrust Force, lbs	Compute Top y vs. Pile Length	Run Analysis
1	1	V = 1551. lbs	M = 167533. in-lbs	1531.	No	Yes

V = shear force applied normal to pile axis
M = bending moment applied to pile head
y = lateral deflection normal to pile axis
S = pile slope relative to original pile batter angle
R = rotational stiffness applied to pile head
Values of top y vs. pile lengths can be computed only for load types with specified shear loading (Load Types 1, 2, and 3).
Thrust force is assumed to be acting axially for all pile batter angles.

Computations of Nominal Moment Capacity and Nonlinear Bending Stiffness

---

Axial thrust force values were determined from pile-head loading conditions

Number of Pile Sections Analyzed = 1

Pile Section No. 1:

Dimensions and Properties of Drilled Shaft (Bored Pile):

Length of Section = 16.000000 ft
Shaft Diameter = 24.000000 in

Concrete Cover Thickness (to edge of long. rebar)	=	4.000000	in
Number of Reinforcing Bars	=	12	bars
Yield Stress of Reinforcing Bars	=	60000.	psi
Modulus of Elasticity of Reinforcing Bars	=	29000000.	psi
Gross Area of Shaft	=	452.389342	sq. in.
Total Area of Reinforcing Steel	=	9.480000	sq. in.
Area Ratio of Steel Reinforcement	=	2.10	percent
Edge-to-Edge Bar Spacing	=	2.882286	in
Maximum Concrete Aggregate Size	=	0.500000	in
Ratio of Bar Spacing to Aggregate Size	=	5.76	
Offset of Center of Rebar Cage from Center of Pile	=	0.0000	in

Axial Structural Capacities:

Nom. Axial Structural Capacity = 0.85 Fc Ac + Fy As	=	2074.692	kips
Tensile Load for Cracking of Concrete	=	-215.928	kips
Nominal Axial Tensile Capacity	=	-568.800	kips

Reinforcing Bar Dimensions and Positions Used in Computations:

Bar Number	Bar Diam. inches	Bar Area sq. in.	X inches	Y inches
1	1.000000	0.790000	7.500000	0.00000
2	1.000000	0.790000	6.495191	3.750000
3	1.000000	0.790000	3.750000	6.495191
4	1.000000	0.790000	0.00000	7.500000
5	1.000000	0.790000	-3.75000	6.495191
6	1.000000	0.790000	-6.49519	3.750000
7	1.000000	0.790000	-7.50000	0.00000
8	1.000000	0.790000	-6.49519	-3.75000
9	1.000000	0.790000	-3.75000	-6.49519
10	1.000000	0.790000	0.00000	-7.50000
11	1.000000	0.790000	3.750000	-6.49519
12	1.000000	0.790000	6.495191	-3.75000

NOTE: The positions of the above rebars were computed by LPile

Minimum spacing between any two bars not equal to zero = 2.882 inches
between bars 7 and 8.

Ratio of bar spacing to maximum aggregate size = 5.76

Concrete Properties:

Compressive Strength of Concrete = 4000. psi
Modulus of Elasticity of Concrete = 3604997. psi
Modulus of Rupture of Concrete = -474.34165 psi
Compression Strain at Peak Stress = 0.001886
Tensile Strain at Fracture of Concrete = -0.0001154
Maximum Coarse Aggregate Size = 0.500000 in

Number of Axial Thrust Force Values Determined from Pile-head Loadings = 1

Number	Axial Thrust Force kips
1	1.531

Definitions of Run Messages and Notes:

C = concrete in section has cracked in tension.
Y = stress in reinforcing steel has reached yield stress.
T = ACI 318 criteria for tension-controlled section met, tensile strain in reinforcement exceeds 0.005 while simultaneously compressive strain in concrete more than 0.003. See ACI 318-14, Section 21.2.3.
Z = depth of tensile zone in concrete section is less than 10 percent of section depth.

Bending Stiffness (EI) = Computed Bending Moment / Curvature.
Position of neutral axis is measured from edge of compression side of pile.
Compressive stresses and strains are positive in sign.
Tensile stresses and strains are negative in sign.

Axial Thrust Force = 1.531 kips

Bending Max Conc Curvature rad/in.	Bending Max Steel Stress ksi	Bending Moment Stress in-kip	Run Stiffness kip-in2	Depth to N Axis in	Max Comp Strain in/in	Max Tens Strain in/in	Msg
0.00000125	94.3897384	75511791.		12.5704778	0.00001571	-0.00001429	
0.0657335	0.3121298						
0.00000250	188.3206657	75328266.		12.2861655	0.00003072	-0.00002928	
0.1279570	0.6036470						
0.00000375	281.7912546	75144335.		12.1913986	0.00004572	-0.00004428	
0.1896846	0.8951646						
0.00000500	374.8015047	74960301.		12.1440181	0.00006072	-0.00005928	

```
 0.2509163     1.1866826
0.00000625   467.3514161     74776227.    12.1155921    0.00007572   -0.00007428
 0.3116520     1.4782011
0.00000750   559.4409887     74592132.    12.0966433    0.00009072   -0.00008928
 0.3718918     1.7697199
0.00000875   651.0702224     74408025.    12.0831101     0.0001057    -0.000104
 0.4316357     2.0612392
0.00001000   651.0702224     65107022.     7.2959388    0.00007296    -0.000167
 0.2985549    -3.695778 C
0.00001125   651.0702224     57872909.     7.2757617    0.00008185    -0.000188
 0.3341386    -4.164333 C
0.00001250   651.0702224     52085618.     7.2601336    0.00009075    -0.000209
 0.3695763    -4.632702 C
0.00001375   651.0702224     47350562.     7.2478157    0.00009966    -0.000230
 0.4048679    -5.100883 C
0.00001500   651.0702224     43404681.     7.2379820     0.0001086    -0.000251
 0.4400130    -5.568878 C
0.00001625   651.0702224     40065860.     7.2300608     0.0001175    -0.000273
 0.4750113    -6.036684 C
0.00001750   651.0702224     37204013.     7.2236435     0.0001264    -0.000294
 0.5098625    -6.504301 C
0.00001875   651.0702224     34723745.     7.2184308     0.0001353    -0.000315
 0.5445664    -6.971728 C
0.00002000   651.0702224     32553511.     7.2141981     0.0001443    -0.000336
 0.5791226    -7.438965 C
0.00002125   651.0702224     30638599.     7.2107734     0.0001532    -0.000357
 0.6135309    -7.906011 C
0.00002250   651.0702224     28936454.     7.2080234     0.0001622    -0.000378
 0.6477909    -8.372865 C
0.00002375   651.0702224     27413483.     7.2058424     0.0001711    -0.000399
 0.6819024    -8.839526 C
0.00002500   651.0702224     26042809.     7.2041462     0.0001801    -0.000420
 0.7158651    -9.305994 C
0.00002625   651.0702224     24802675.     7.2028665     0.0001891    -0.000441
 0.7496787    -9.772268 C
0.00002750   651.0702224     23675281.     7.2019475     0.0001981    -0.000462
 0.7833429   -10.238347 C
0.00002875   651.0702224     22645921.     7.2013429     0.0002070    -0.000483
 0.8168573   -10.704230 C
0.00003000   651.0702224     21702341.     7.2010144     0.0002160    -0.000504
 0.8502217   -11.169917 C
0.00003125   651.0702224     20834247.     7.2009296     0.0002250    -0.000525
 0.8834358   -11.635407 C
0.00003250   651.1366545     20034974.     7.2010613     0.0002340    -0.000546
 0.9164992   -12.100700 C
0.00003375   675.5724529     20016962.     7.2013861     0.0002430    -0.000567
 0.9494116   -12.565793 C
0.00003500   699.9839821     19999542.     7.2018842     0.0002521    -0.000588
 0.9821728   -13.030687 C
0.00003625   724.3711599     19982653.     7.2025384     0.0002611    -0.000609
```

 1.0147825   -13.495381 C
0.00003750   748.7339032   19966237.   7.2033338   0.0002701   -0.000630
 1.0472402   -13.959874 C
0.00003875   773.0721286   19950248.   7.2042574   0.0002792   -0.000651
 1.0795457   -14.424166 C
0.00004000   797.3857521   19934644.   7.2052980   0.0002882   -0.000672
 1.1116987   -14.888254 C
0.00004125   821.6746892   19919386.   7.2064454   0.0002973   -0.000693
 1.1436989   -15.352140 C
0.00004250   845.9388547   19904444.   7.2076911   0.0003063   -0.000714
 1.1755459   -15.815821 C
0.00004375   870.1781629   19889787.   7.2090271   0.0003154   -0.000735
 1.2072394   -16.279297 C
0.00004500   894.3925275   19875389.   7.2104467   0.0003245   -0.000756
 1.2387791   -16.742567 C
0.00004625   918.5818616   19861229.   7.2119435   0.0003336   -0.000776
 1.2701647   -17.205631 C
0.00004750   942.7460780   19847286.   7.2135123   0.0003426   -0.000797
 1.3013958   -17.668487 C
0.00004875   966.8850884   19833540.   7.2151479   0.0003517   -0.000818
 1.3324721   -18.131135 C
0.00005125   1015.   19806578.   7.2186026   0.0003700   -0.000860
 1.3941589   -19.055802 C
0.00005375   1063.   19780229.   7.2222771   0.0003882   -0.000902
 1.4552225   -19.979625 C
0.00005625   1111.   19754397.   7.2261464   0.0004065   -0.000944
 1.5156602   -20.902598 C
0.00005875   1159.   19729004.   7.2301898   0.0004248   -0.000985
 1.5754692   -21.824714 C
0.00006125   1207.   19703985.   7.2343899   0.0004431   -0.001027
 1.6346467   -22.745965 C
0.00006375   1255.   19679283.   7.2387322   0.0004615   -0.001069
 1.6931899   -23.666344 C
0.00006625   1302.   19654851.   7.2432046   0.0004799   -0.001110
 1.7510960   -24.585843 C
0.00006875   1350.   19630648.   7.2477965   0.0004983   -0.001152
 1.8083620   -25.504456 C
0.00007125   1397.   19606639.   7.2524991   0.0005167   -0.001193
 1.8649850   -26.422174 C
0.00007375   1444.   19582793.   7.2573047   0.0005352   -0.001235
 1.9209621   -27.338989 C
0.00007625   1491.   19559084.   7.2622067   0.0005537   -0.001276
 1.9762903   -28.254895 C
0.00007875   1538.   19535489.   7.2671995   0.0005723   -0.001318
 2.0309665   -29.169883 C
0.00008125   1585.   19511985.   7.2722780   0.0005909   -0.001359
 2.0849876   -30.083945 C
0.00008375   1632.   19488556.   7.2774381   0.0006095   -0.001401
 2.1383506   -30.997072 C
0.00008625   1679.   19465184.   7.2826759   0.0006281   -0.001442

 2.1910523   -31.909257 C
0.00008875   1725.   19441855.   7.2879882   0.0006468   -0.001483
 2.2430894   -32.820490 C
0.00009125   1772.   19418556.   7.2933721   0.0006655   -0.001524
 2.2944588   -33.730764 C
0.00009375   1818.   19395274.   7.2988251   0.0006843   -0.001566
 2.3451571   -34.640069 C
0.00009625   1865.   19372000.   7.3043451   0.0007030   -0.001607
 2.3951810   -35.548397 C
0.00009875   1911.   19348721.   7.3099300   0.0007219   -0.001648
 2.4445272   -36.455738 C
 0.0001013   1957.   19325431.   7.3155782   0.0007407   -0.001689
 2.4931922   -37.362083 C
 0.0001038   2003.   19302127.   7.3212463   0.0007596   -0.001730
 2.5411613   -38.267550 C
 0.0001063   2048.   19278820.   7.3268283   0.0007785   -0.001772
 2.5884029   -39.172460 C
 0.0001088   2094.   19255482.   7.3324667   0.0007974   -0.001813
 2.6349513   -40.076383 C
 0.0001113   2140.   19232105.   7.3381605   0.0008164   -0.001854
 2.6808029   -40.979309 C
 0.0001138   2185.   19208684.   7.3439089   0.0008354   -0.001895
 2.7259543   -41.881230 C
 0.0001163   2230.   19185214.   7.3497113   0.0008544   -0.001936
 2.7704018   -42.782136 C
 0.0001188   2275.   19161688.   7.3555669   0.0008735   -0.001977
 2.8141418   -43.682016 C
 0.0001213   2320.   19138101.   7.3614754   0.0008926   -0.002017
 2.8571706   -44.580862 C
 0.0001238   2365.   19114450.   7.3674363   0.0009117   -0.002058
 2.8994843   -45.478663 C
 0.0001263   2410.   19090729.   7.3734492   0.0009309   -0.002099
 2.9410793   -46.375409 C
 0.0001288   2455.   19066934.   7.3795140   0.0009501   -0.002140
 2.9819515   -47.271089 C
 0.0001313   2499.   19043061.   7.3856303   0.0009694   -0.002181
 3.0220972   -48.165694 C
 0.0001338   2544.   19019106.   7.3917981   0.0009887   -0.002221
 3.0615123   -49.059213 C
 0.0001363   2588.   18995066.   7.3980173   0.0010080   -0.002262
 3.1001928   -49.951634 C
 0.0001388   2632.   18970935.   7.4042878   0.0010273   -0.002303
 3.1381345   -50.842946 C
 0.0001413   2676.   18946712.   7.4106098   0.0010467   -0.002343
 3.1753333   -51.733139 C
 0.0001438   2720.   18922393.   7.4169833   0.0010662   -0.002384
 3.2117850   -52.622201 C
 0.0001463   2764.   18897973.   7.4234083   0.0010857   -0.002424
 3.2474853   -53.510119 C
 0.0001488   2807.   18873451.   7.4298852   0.0011052   -0.002465

```
3.2824298    -54.396882 C
0.0001588         2980.     18774268.     7.4563149     0.0011837     -0.002626
3.4145604    -57.932140 C
0.0001688         3150.     18666275.     7.4826813     0.0012627     -0.002787
3.5340078    -60.000000 CY
0.0001788         3299.     18455239.     7.4959244     0.0013399     -0.002950
3.6375234    -60.000000 CY
0.0001888         3421.     18123687.     7.4917650     0.0014141     -0.003116
3.7247043    -60.000000 CY
0.0001988         3505.     17632920.     7.4619846     0.0014831     -0.003287
3.7949724    -60.000000 CY
0.0002088         3578.     17140737.     7.4305173     0.0015511     -0.003459
3.8541387    -60.000000 CY
0.0002188         3650.     16687980.     7.4041948     0.0016197     -0.003630
3.9035834    -60.000000 CY
0.0002288         3722.     16269301.     7.3824249     0.0016887     -0.003801
3.9430908    -60.000000 CY
0.0002388         3789.     15871921.     7.3629620     0.0017579     -0.003972
3.9722842    -60.000000 CY
0.0002488         3843.     15448339.     7.3355841     0.0018247     -0.004145
3.9906095    -60.000000 CY
0.0002588         3879.     14989826.     7.2965791     0.0018880     -0.004322
3.9990328    -60.000000 CY
0.0002688         3907.     14537764.     7.2554624     0.0019499     -0.004500
3.9987671    -60.000000 CY
0.0002788         3934.     14113829.     7.2186927     0.0020122     -0.004678
3.9980815    -60.000000 CY
0.0002888         3961.     13716273.     7.1861389     0.0020750     -0.004855
3.9967432    -60.000000 CY
0.0002988         3986.     13342560.     7.1573548     0.0021383     -0.005032
3.9996743    -60.000000 CY
0.0003088         4011.     12990294.     7.1320369     0.0022020     -0.005208
3.9996476    -60.000000 CY
0.0003188         4035.     12657736.     7.1097627     0.0022662     -0.005384
3.9981300    -60.000000 CY
0.0003288         4058.     12343283.     7.0901830     0.0023309     -0.005559
3.9966526    -60.000000 CY
0.0003388         4080.     12045182.     7.0726937     0.0023959     -0.005734
3.9996007    -60.000000 CY
0.0003488         4102.     11762194.     7.0569374     0.0024611     -0.005909
3.9968523    -60.000000 CY
0.0003588         4123.     11493437.     7.0432005     0.0025267     -0.006083
3.9999687    -60.000000 CY
0.0003688         4144.     11237503.     7.0314844     0.0025929     -0.006257
3.9976561    -60.000000 CY
0.0003788         4164.     10993715.     7.0212518     0.0026593     -0.006431
3.9998814    -60.000000 CY
0.0003888         4183.     10759463.     7.0120245     0.0027259     -0.006604
3.9975486    -60.000000 CY
0.0003988         4199.     10529741.     7.0008071     0.0027916     -0.006778
```

```
    3.9999833    -60.000000 CY
    0.0004088         4212.     10304889.     6.9883180     0.0028565     -0.006954
    3.9959736    -60.000000 CY
    0.0004188         4223.     10085084.     6.9742679     0.0029205     -0.007130
    3.9995020    -60.000000 CY
    0.0004288         4231.      9867756.     6.9574073     0.0029830     -0.007307
    3.9948997    -60.000000 CY
    0.0004388         4237.      9657233.     6.9404446     0.0030451     -0.007485
    3.9969483    -60.000000 CYT
    0.0004488         4241.      9450373.     6.9212621     0.0031059     -0.007664
    3.9995982    -60.000000 CYT
    0.0004588         4244.      9251355.     6.9029363     0.0031667     -0.007843
    3.9955163    -60.000000 CYT
    0.0004688         4247.      9060334.     6.8858207     0.0032277     -0.008022
    3.9952804    -60.000000 CYT
    0.0004788         4250.      8877067.     6.8697396     0.0032889     -0.008201
    3.9987283    -60.000000 CYT
    0.0004888         4253.      8701087.     6.8546455     0.0033502     -0.008380
    3.9999940    -60.000000 CYT
    0.0004988         4255.      8531753.     6.8407169     0.0034118     -0.008558
    3.9908179    -60.000000 CYT
    0.0005088         4258.      8368701.     6.8265212     0.0034730     -0.008737
    3.9957302    -60.000000 CYT
    0.0005188         4260.      8211774.     6.8130874     0.0035343     -0.008916
    3.9987955    -60.000000 CYT
    0.0005288         4262.      8060633.     6.8004376     0.0035957     -0.009094
    3.9999847    -60.000000 CYT
    0.0005388         4264.      7914796.     6.7887542     0.0036574     -0.009273
    3.9919674    -60.000000 CYT
    0.0005488         4266.      7774138.     6.7777555     0.0037193     -0.009451
    3.9933988    -60.000000 CYT
    0.0006088         4266.      7007898.     6.7766348     0.0041253     -0.010485
    3.9992664    -60.000000 CYT


-------------------------------------------------------------------------------
   Summary of Results for Nominal Moment Capacity for Section 1
-------------------------------------------------------------------------------

Moment values interpolated at maximum compressive strain = 0.003
or maximum developed moment if pile fails at smaller strains.

 Load           Axial Thrust        Nominal Mom. Cap.      Max. Comp.      Max.
Tens.
  No.              kips                 in-kip               Strain
Strain
 ----         ----------------     ------------------     ------------
------------
   1                1.531             4232.528           0.00300000
-0.00735571
```

Note that the values of moment capacity in the table above are not
factored by a strength reduction factor (phi-factor).

In ACI 318, the value of the strength reduction factor depends on whether
the transverse reinforcing steel bars are tied hoops (0.65) or spirals (0.75).

The above values should be multiplied by the appropriate strength reduction
factor to compute ultimate moment capacity according to ACI 318,
or the value required by the design standard being followed.

The following table presents factored moment capacities and corresponding
bending stiffnesses computed for common resistance factor values used for
reinforced concrete sections.

Axial Load No.	Resist. Factor	Nominal Ax. Thrust kips	Nominal Moment Cap in-kips	Ult. (Fac) Ax. Thrust kips	Ult. (Fac) Moment Cap in-kips	Bend. Stiff. at Ult Mom kip-in^2
1	0.65	1.530600	4233.	0.994890	2751.	18905056.
1	0.75	1.530600	4233.	1.147950	3174.	18631614.
1	0.90	1.530600	4233.	1.377540	3809.	15714293.

Layering Correction Equivalent Depths of Soil & Rock Layers

Layer No.	Top of Layer Below Pile Head ft	Equivalent Top Depth Below Grnd Surf ft	Same Layer Type As Layer Above	Layer is Rock or is Below Rock Layer	F0 Integral for Layer lbs	F1 Integral for Layer lbs
1	0.00	0.00	N.A.	No	0.00	11790.
2	4.0000	4.0000	Yes	No	11790.	69203.
3	11.5000	8.6139	Yes	No	80993.	137183.
4	17.0000	17.0000	No	Yes	N.A.	N.A.

Notes: The F0 integral of Layer n+1 equals the sum of the F0 and F1 integrals

for Layer n. Layering correction equivalent depths are computed only for soil types with both shallow-depth and deep-depth expressions for peak lateral load transfer. These soil types are soft and stiff clays, non-liquefied sands, and cemented c-phi soil.

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

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

Shear force at pile head = 1551.2 lbs
Applied moment at pile head = 167532.7 in-lbs
Axial thrust load on pile head = 1530.6 lbs

Depth X	Deflect. y	Bending Moment	Shear Force	Slope S	Total Stress	Bending Stiffness	Soil Res. Es*H	Soil Spr. Lat. Load	Distrib. p
feet	inches	in-lbs	lbs	radians	psi*	lb-in^2	lb/inch	lb/inch	lb/inch
0.00	0.06009	167533.	1551.	-5.90E-04	0.00	7.54E+10	0.00	0.00	0.00
0.1600	0.05896	170513.	1549.	-5.86E-04	0.00	7.54E+10	-2.830	92.1600	0.00
0.3200	0.05784	173482.	1540.	-5.82E-04	0.00	7.53E+10	-5.553	184.3200	0.00
0.4800	0.05673	176432.	1527.	-5.77E-04	0.00	7.53E+10	-8.169	276.4800	0.00
0.6400	0.05563	179351.	1509.	-5.73E-04	0.00	7.53E+10	-10.680	368.6400	0.00
0.8000	0.05453	182230.	1486.	-5.68E-04	0.00	7.53E+10	-13.087	460.8000	0.00
0.9600	0.05344	185062.	1459.	-5.63E-04	0.00	7.53E+10	-15.392	552.9600	0.00
1.1200	0.05237	187836.	1427.	-5.59E-04	0.00	7.53E+10	-17.595	645.1200	0.00
1.2800	0.05130	190546.	1392.	-5.54E-04	0.00	7.53E+10	-19.699	737.2800	0.00
1.4400	0.05024	193183.	1352.	-5.49E-04	0.00	7.53E+10	-21.704	829.4400	0.00
1.6000	0.04919	195740.	1308.	-5.44E-04	0.00	7.53E+10	-23.611	921.6000	0.00
1.7600	0.04815	198210.	1261.	-5.39E-04	0.00	7.53E+10			

```
-25.424      1014.       0.00
    1.9200    0.04712    200587.      1211.  -5.34E-04       0.00   7.53E+10
-27.142      1106.       0.00
    2.0800    0.04610    202863.      1157.  -5.29E-04       0.00   7.53E+10
-28.767      1198.       0.00
    2.2400    0.04509    205033.      1100.  -5.24E-04       0.00   7.53E+10
-30.301      1290.       0.00
    2.4000    0.04409    207092.      1041.  -5.18E-04       0.00   7.53E+10
-31.745      1382.       0.00
    2.5600    0.04310    209033.   978.5917  -5.13E-04       0.00   7.53E+10
-33.101      1475.       0.00
    2.7200    0.04212    210852.   913.8189  -5.08E-04       0.00   7.53E+10
-34.371      1567.       0.00
    2.8800    0.04115    212545.   846.6906  -5.02E-04       0.00   7.53E+10
-35.555      1659.       0.00
    3.0400    0.04019    214107.   777.3690  -4.97E-04       0.00   7.53E+10
-36.655      1751.       0.00
    3.2000    0.03924    215533.   706.0129  -4.91E-04       0.00   7.53E+10
-37.674      1843.       0.00
    3.3600    0.03831    216821.   632.7782  -4.86E-04       0.00   7.53E+10
-38.612      1935.       0.00
    3.5200    0.03738    217966.   557.8179  -4.80E-04       0.00   7.53E+10
-39.472      2028.       0.00
    3.6800    0.03646    218965.   481.2818  -4.75E-04       0.00   7.53E+10
-40.254      2120.       0.00
    3.8400    0.03556    219817.   403.3166  -4.69E-04       0.00   7.52E+10
-40.960      2212.       0.00
    4.0000    0.03466    220517.   332.0518  -4.63E-04       0.00   7.52E+10
-33.274      1843.       0.00
    4.1600    0.03378    221095.   267.7356  -4.58E-04       0.00   7.52E+10
-33.722      1917.       0.00
    4.3200    0.03290    221548.   202.6137  -4.52E-04       0.00   7.52E+10
-34.113      1991.       0.00
    4.4800    0.03204    221875.   136.7937  -4.46E-04       0.00   7.52E+10
-34.449      2064.       0.00
    4.6400    0.03119    222076.    70.3809  -4.41E-04       0.00   7.52E+10
-34.731      2138.       0.00
    4.8000    0.03035    222148.     3.4779  -4.35E-04       0.00   7.52E+10
-34.960      2212.       0.00
    4.9600    0.02952    222092.    -63.815  -4.29E-04       0.00   7.52E+10
-35.137      2286.       0.00
    5.1200    0.02870    221906.   -131.399  -4.24E-04       0.00   7.52E+10
-35.264      2359.       0.00
    5.2800    0.02789    221589.   -199.180  -4.18E-04       0.00   7.52E+10
-35.341      2433.       0.00
    5.4400    0.02709    221143.   -267.064  -4.13E-04       0.00   7.52E+10
-35.371      2507.       0.00
    5.6000    0.02631    220566.   -334.961  -4.07E-04       0.00   7.52E+10
-35.354      2580.       0.00
    5.7600    0.02553    219859.   -402.781  -4.01E-04       0.00   7.52E+10
```

-35.292 2654. 0.00
5.9200 0.02476 219022. -470.439 -3.96E-04 0.00 7.53E+10
-35.185 2728. 0.00
6.0800 0.02401 218055. -537.851 -3.90E-04 0.00 7.53E+10
-35.035 2802. 0.00
6.2400 0.02327 216959. -604.935 -3.85E-04 0.00 7.53E+10
-34.844 2875. 0.00
6.4000 0.02253 215734. -671.612 -3.79E-04 0.00 7.53E+10
-34.611 2949. 0.00
6.5600 0.02181 214382. -737.804 -3.74E-04 0.00 7.53E+10
-34.339 3023. 0.00
6.7200 0.02110 212903. -803.437 -3.68E-04 0.00 7.53E+10
-34.028 3097. 0.00
6.8800 0.02040 211299. -868.437 -3.63E-04 0.00 7.53E+10
-33.680 3170. 0.00
7.0400 0.01971 209571. -932.734 -3.57E-04 0.00 7.53E+10
-33.296 3244. 0.00
7.2000 0.01903 207720. -996.259 -3.52E-04 0.00 7.53E+10
-32.876 3318. 0.00
7.3600 0.01835 205747. -1059. -3.47E-04 0.00 7.53E+10
-32.422 3391. 0.00
7.5200 0.01769 203655. -1121. -3.41E-04 0.00 7.53E+10
-31.934 3465. 0.00
7.6800 0.01704 201446. -1182. -3.36E-04 0.00 7.53E+10
-31.414 3539. 0.00
7.8400 0.01640 199120. -1241. -3.31E-04 0.00 7.53E+10
-30.863 3613. 0.00
8.0000 0.01577 196681. -1300. -3.26E-04 0.00 7.53E+10
-30.281 3686. 0.00
8.1600 0.01515 194130. -1358. -3.21E-04 0.00 7.53E+10
-29.670 3760. 0.00
8.3200 0.01454 191470. -1414. -3.16E-04 0.00 7.53E+10
-29.029 3834. 0.00
8.4800 0.01394 188702. -1469. -3.11E-04 0.00 7.53E+10
-28.361 3908. 0.00
8.6400 0.01334 185830. -1523. -3.07E-04 0.00 7.53E+10
-27.666 3981. 0.00
8.8000 0.01276 182857. -1575. -3.02E-04 0.00 7.53E+10
-26.944 4055. 0.00
8.9600 0.01218 179783. -1626. -2.97E-04 0.00 7.53E+10
-26.197 4129. 0.00
9.1200 0.01162 176614. -1676. -2.93E-04 0.00 7.53E+10
-25.425 4202. 0.00
9.2800 0.01106 173350. -1724. -2.88E-04 0.00 7.53E+10
-24.629 4276. 0.00
9.4400 0.01051 169996. -1770. -2.84E-04 0.00 7.53E+10
-23.809 4350. 0.00
9.6000 0.00997 166553. -1815. -2.80E-04 0.00 7.54E+10
-22.965 4424. 0.00
9.7600 0.00943 163027. -1859. -2.75E-04 0.00 7.54E+10

```
-22.100      4497.       0.00
    9.9200    0.00891    159418.     -1900.  -2.71E-04       0.00   7.54E+10
-21.212      4571.       0.00
   10.0800    0.00839    155732.     -1940.  -2.67E-04       0.00   7.54E+10
-20.303      4645.       0.00
   10.2400    0.00788    151970.     -1978.  -2.63E-04       0.00   7.54E+10
-19.374      4719.       0.00
   10.4000    0.00738    148138.     -2014.  -2.60E-04       0.00   7.54E+10
-18.423      4792.       0.00
   10.5600    0.00689    144237.     -2049.  -2.56E-04       0.00   7.54E+10
-17.452      4866.       0.00
   10.7200    0.00640    140272.     -2081.  -2.52E-04       0.00   7.54E+10
-16.462      4940.       0.00
   10.8800    0.00592    136246.     -2112.  -2.49E-04       0.00   7.54E+10
-15.452      5014.       0.00
   11.0400    0.00544    132163.     -2141.  -2.45E-04       0.00   7.54E+10
-14.422      5087.       0.00
   11.2000    0.00498    128027.     -2167.  -2.42E-04       0.00   7.54E+10
-13.374      5161.       0.00
   11.3600    0.00451    123842.     -2192.  -2.39E-04       0.00   7.54E+10
-12.306      5235.       0.00
   11.5200    0.00406    119612.     -2271.  -2.36E-04       0.00   7.54E+10
-70.127     33178.       0.00
   11.6800    0.00361    115123.     -2399.  -2.33E-04       0.00   7.54E+10
-63.223     33638.       0.00
   11.8400    0.00316    110400.     -2514.  -2.30E-04       0.00   7.55E+10
-56.203     34099.       0.00
   12.0000    0.00273    105471.     -2615.  -2.27E-04       0.00   7.55E+10
-49.067     34560.       0.00
   12.1600    0.00229    100361.     -2702.  -2.24E-04       0.00   7.55E+10
-41.815     35021.       0.00
   12.3200    0.00186     95096.     -2775.  -2.22E-04       0.00   7.55E+10
-34.445     35482.       0.00
   12.4800    0.00144     89705.     -2834.  -2.20E-04       0.00   7.55E+10
-26.956     35942.       0.00
   12.6400    0.00102     84214.     -2879.  -2.17E-04       0.00   7.55E+10
-19.346     36403.       0.00
   12.8000   6.05E-04     78652.     -2908.  -2.15E-04       0.00   7.55E+10
-11.615     36864.       0.00
   12.9600   1.93E-04     73047.     -2923.  -2.13E-04       0.00   7.55E+10
-3.758     37325.       0.00
   13.1200  -2.15E-04     67428.     -2923.  -2.12E-04       0.00   7.55E+10
4.2260     37786.       0.00
   13.2800  -6.19E-04     61825.     -2907.  -2.10E-04       0.00   7.55E+10
12.3403     38246.       0.00
   13.4400   -0.00102     56267.     -2875.  -2.09E-04       0.00   7.55E+10
20.5880     38707.       0.00
   13.6000   -0.00142     50785.     -2828.  -2.07E-04       0.00   7.55E+10
28.9725     39168.       0.00
   13.7600   -0.00182     45410.     -2764.  -2.06E-04       0.00   7.55E+10
```

```
37.4974     39629.       0.00
   13.9200   -0.00221     40173.     -2684.  -2.05E-04       0.00   7.55E+10
46.1663     40090.       0.00
   14.0800   -0.00260     35107.     -2586.  -2.04E-04       0.00   7.55E+10
54.9830     40550.       0.00
   14.2400   -0.00299     30243.     -2472.  -2.03E-04       0.00   7.55E+10
63.9515     41011.       0.00
   14.4000   -0.00338     25615.     -2341.  -2.02E-04       0.00   7.55E+10
73.0755     41472.       0.00
   14.5600   -0.00377     21256.     -2191.  -2.02E-04       0.00   7.55E+10
82.3591     41933.       0.00
   14.7200   -0.00416     17201.     -2024.  -2.01E-04       0.00   7.55E+10
91.8059     42394.       0.00
   14.8800   -0.00454     13484.     -1839.  -2.01E-04       0.00   7.55E+10
101.4196    42854.       0.00
   15.0400   -0.00493     10141.     -1635.  -2.01E-04       0.00   7.55E+10
111.2038    43315.       0.00
   15.2000   -0.00531      7208.     -1412.  -2.00E-04       0.00   7.55E+10
121.1617    43776.       0.00
   15.3600   -0.00570      4722.     -1169.  -2.00E-04       0.00   7.55E+10
131.2962    44237.       0.00
   15.5200   -0.00608      2719.   -907.229  -2.00E-04       0.00   7.55E+10
141.6099    44698.       0.00
   15.6800   -0.00647      1239.   -625.263  -2.00E-04       0.00   7.55E+10
152.1050    45158.       0.00
   15.8400   -0.00685   319.4745   -322.971  -2.00E-04       0.00   7.55E+10
162.7830    45619.       0.00
   16.0000   -0.00724       0.00       0.00  -2.00E-04       0.00   7.55E+10
173.6449    23040.       0.00
```

* This analysis computed pile response using nonlinear moment-curvature relationships. Values of total stress due to combined axial and bending stresses are computed only for elastic sections only and do not equal the actual stresses in concrete and steel. Stresses in concrete and steel may be interpolated from the output for nonlinear bending properties relative to the magnitude of bending moment developed in the pile.

Output Summary for Load Case No. 1:

```
Pile-head deflection             =     0.06009227 inches
Computed slope at pile head      =     -0.0005904 radians
Maximum bending moment           =        222148. inch-lbs
Maximum shear force              =         -2923. lbs
Depth of maximum bending moment  =     4.80000000 feet below pile head
Depth of maximum shear force     =    12.96000000 feet below pile head
Number of iterations             =              6
Number of zero deflection points =              1
```

Summary of Pile-head Responses for Conventional Analyses

Definitions of Pile-head Loading Conditions:

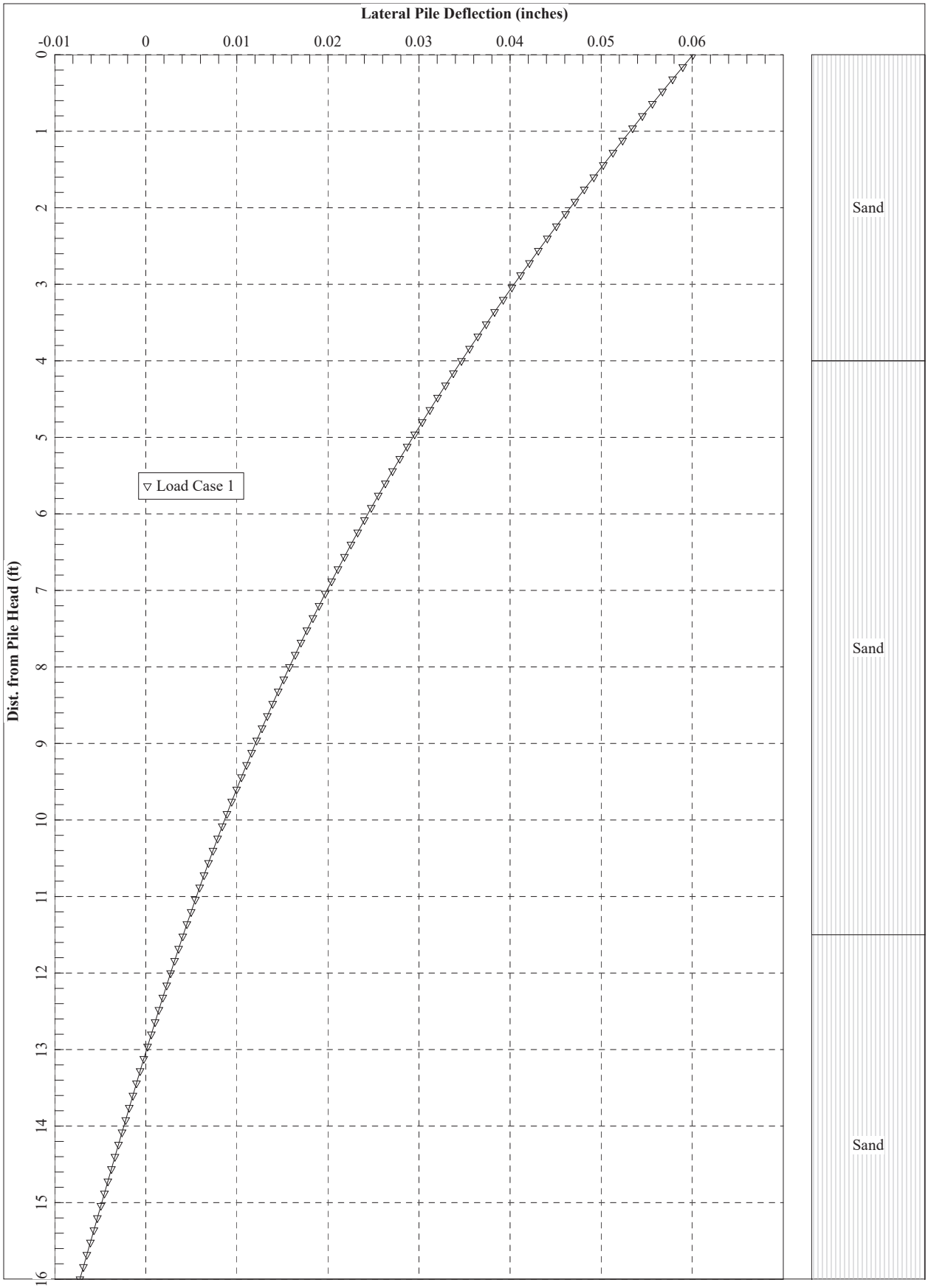
Load Type 1: Load 1 = Shear, V, lbs, and Load 2 = Moment, M, in-lbs
Load Type 2: Load 1 = Shear, V, lbs, and Load 2 = Slope, S, radians
Load Type 3: Load 1 = Shear, V, lbs, and Load 2 = Rot. Stiffness, R, in-lbs/rad.
Load Type 4: Load 1 = Top Deflection, y, inches, and Load 2 = Moment, M, in-lbs
Load Type 5: Load 1 = Top Deflection, y, inches, and Load 2 = Slope, S, radians

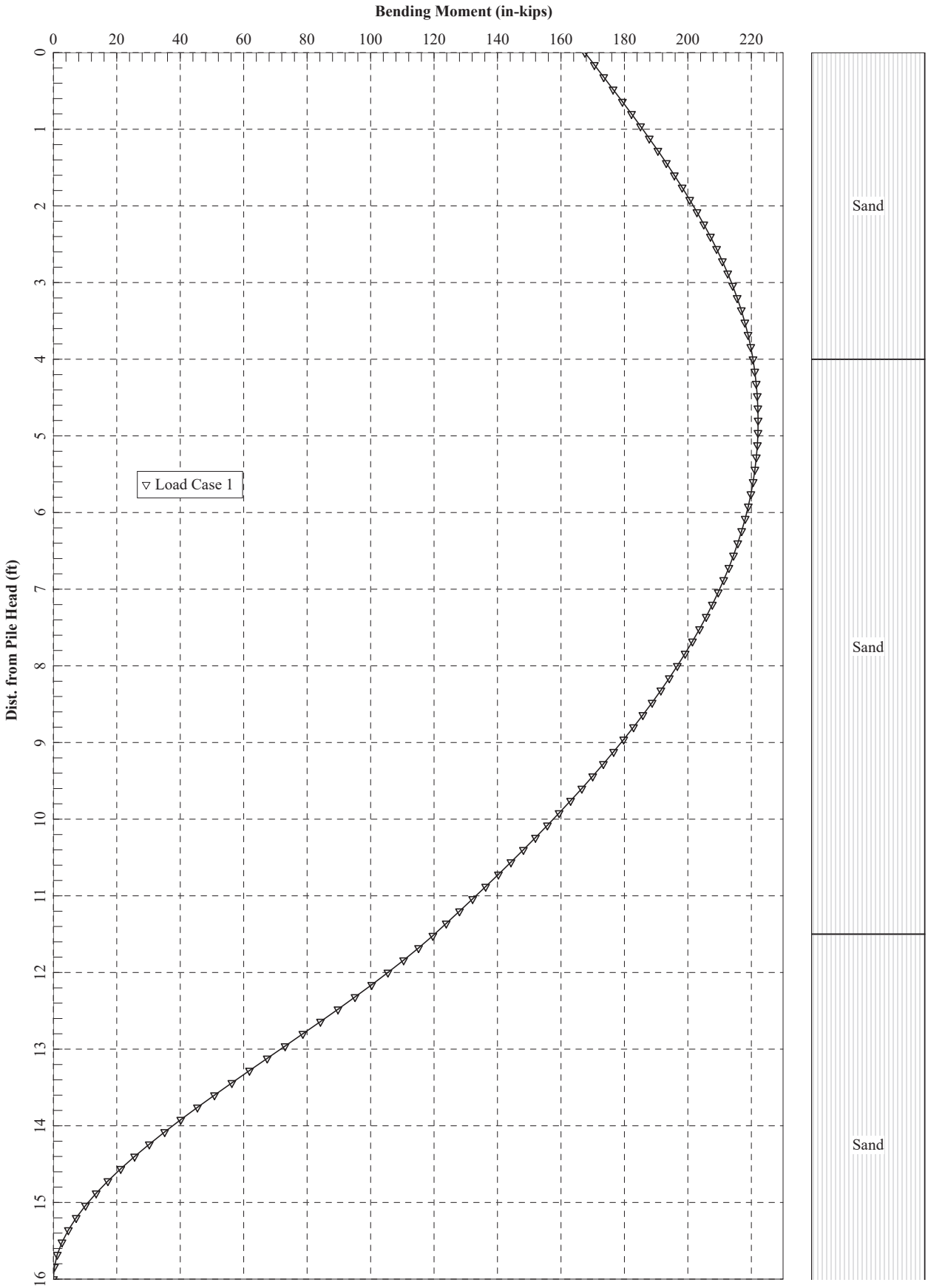
Load Case No.	Load Type 1	Pile-head Load 1	Load Type 2	Pile-head Load 2	Axial Loading lbs	Pile-head Deflection inches	Pile-head Rotation radians	Max Shear in Pile lbs	Max Moment in Pile in-lbs
1	V, lb	1551.	M, in-lb	167533.	1531.	0.06009	-5.90E-04	-2923.	222148.

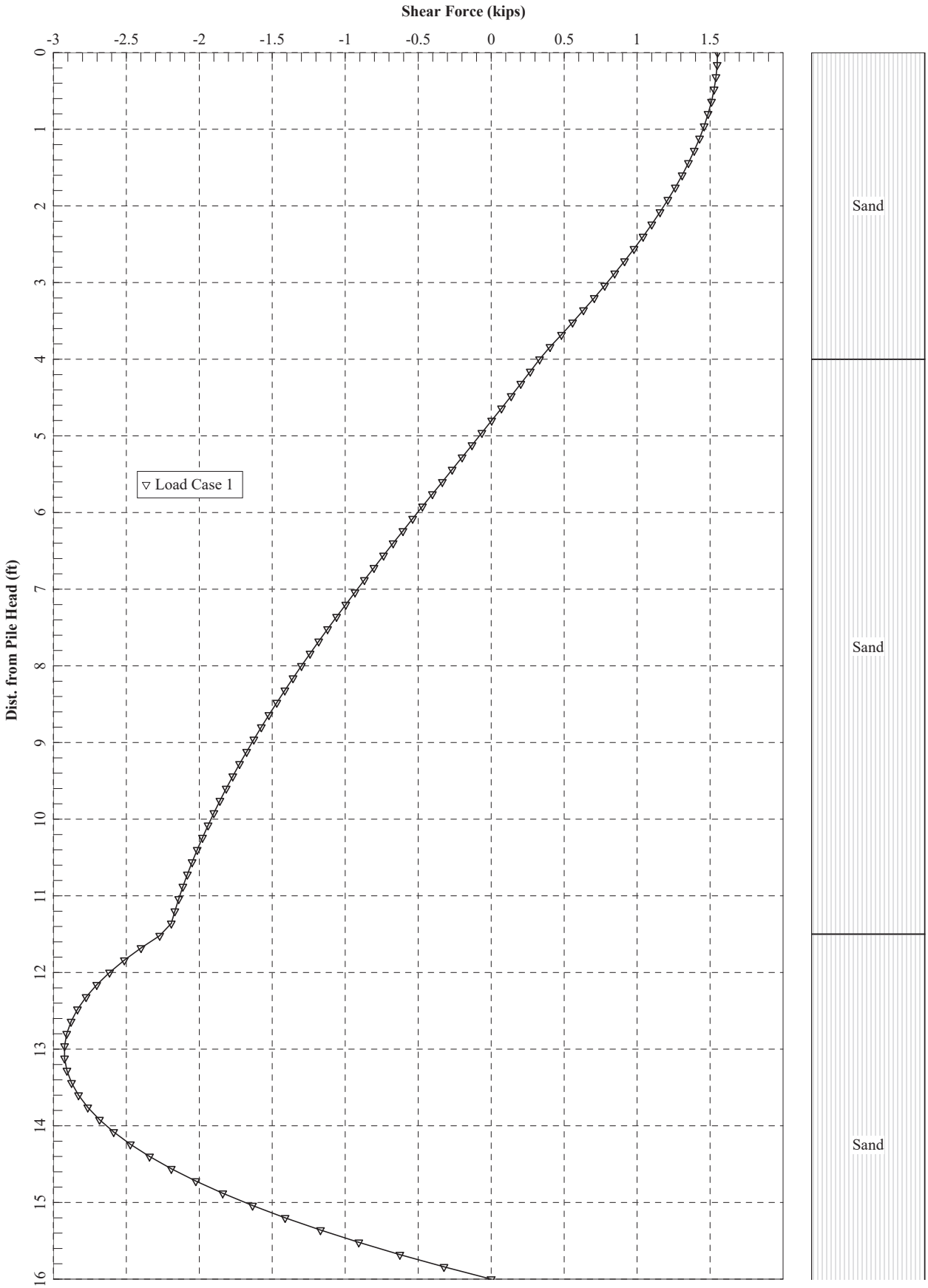
Maximum pile-head deflection = 0.0600922668 inches
Maximum pile-head rotation = -0.0005903745 radians = -0.033826 deg.

The analysis ended normally.

SER-I Load Case Anticipated Deflection (Caisson Bearing in Residual Soil) = 0.06 inches


Lateral Pile Deflection (inches)
-0.01
0
0.01
0.02
0.03
0.04
0.05
0.06
Dist. from Pile Head (ft)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
Load Case 1
Sand
Sand
Sand


Bending Moment (in-kips)
0
20
40
60
80
100
120
140
160
180
200
220
Dist. from Pile Head (ft)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
Load Case 1
Sand
Sand
Sand


Shear Force (kips)
-3
-2.5
-2
-1.5
-1
-0.5
0
0.5
1
1.5
Dist. from Pile Head (ft)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
Load Case 1
Sand
Sand
Sand

STR-I Load Case Results
Caisson Bearing in Residual Soil

```
================================================================================

                    LPile for Windows, Version 2022-12.009

                 Analysis of Individual Piles and Drilled Shafts
               Subjected to Lateral Loading Using the p-y Method
                          © 1985-2022 by Ensoft, Inc.
                              All Rights Reserved

================================================================================
```

By: SMC 07/23
Checked by: RHY 08/23

```
This copy of LPile is being used by:

Gannett Fleming, Inc
Pittsburgh, PA


Serial Number of Security Device: 546957815

This copy of LPile is licensed for exclusive use by:

Gannett Fleming, Inc., LPILE Sm Global, SmGlobal Licens

Use of this software by employees of Gannett Fleming, Inc.
other than those of the office site in LPILE Sm Global, SmGlobal Licens
is a violation of the software license agreement.

--------------------------------------------------------------------------------
                              Files Used for Analysis
--------------------------------------------------------------------------------

Path to file locations:
\Users\schechak\Desktop\SR88 Grade Crossing\

Name of input data file:
SR88 Grade Crossing Caisson (STR-I Load Case) (Caisson Bearing in Residual
Soil).lp12d

Name of output report file:
SR88 Grade Crossing Caisson (STR-I Load Case) (Caisson Bearing in Residual
Soil).lp12o

Name of plot output file:
SR88 Grade Crossing Caisson (STR-I Load Case) (Caisson Bearing in Residual
Soil).lp12p

Name of runtime message file:
SR88 Grade Crossing Caisson (STR-I Load Case) (Caisson Bearing in Residual
Soil).lp12r
```

Date and Time of Analysis

Date: July 28, 2023 Time: 15:05:11

Problem Title

Project Name: SR88 Grade Crossing Gate Foundation

Job Number: 073937.06

Client: Port Authority of Allegheny County

Engineer: S. Chechak

Description:

Program Options and Settings

Computational Options:
- Conventional Analysis

Engineering Units Used for Data Input and Computations:
- US Customary System Units (pounds, feet, inches)

Analysis Control Options:

- Maximum number of iterations allowed	=	500
- Deflection tolerance for convergence	=	1.0000E-05 in
- Maximum allowable deflection	=	100.0000 in

```
 - Number of pile increments                              =          100

Loading Type and Number of Cycles of Loading:
 - Static loading specified

 - Use of p-y modification factors for p-y curves not selected
 - Analysis uses layering correction (Method of Georgiadis)
 - No distributed lateral loads are entered
 - Loading by lateral soil movements acting on pile not selected
 - Input of shear resistance at the pile tip not selected
 - Input of moment resistance at the pile tip not selected
 - Computation of pile-head foundation stiffness matrix not selected
 - Push-over analysis of pile not selected
 - Buckling analysis of pile not selected

Output Options:
 - Output files use decimal points to denote decimal symbols.
 - Values of pile-head deflection, bending moment, shear force, and
   soil reaction are printed for full length of pile.
 - Printing Increment (nodal spacing of output points) = 1
 - No p-y curves to be computed and reported for user-specified depths
 - Print using wide report formats




---------------------------------------------------------------------------
                     Pile Structural Properties and Geometry
---------------------------------------------------------------------------

Number of pile sections defined                          =            1
Total length of pile                                     =       16.000 ft
Depth of ground surface below top of pile                =       0.0000 ft

Pile diameters used for p-y curve computations are defined using 2 points.

p-y curves are computed using pile diameter values interpolated with depth over
the length of the pile. A summary of values of pile diameter vs. depth follows.

            Depth Below           Pile
Point        Pile Head          Diameter
 No.            feet              inches
-----      -------------     -------------
  1             0.000           24.0000
  2            16.000           24.0000


Input Structural Properties for Pile Sections:
----------------------------------------------
```

Pile Section No. 1:

Section 1 is a round drilled shaft, bored pile, or CIDH pile

Length of section	=	16.000000 ft
Shaft Diameter	=	24.000000 in

Soil and Rock Layering Information

The soil profile is modelled using 4 layers

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

Distance from top of pile to top of layer	=	0.0000 ft
Distance from top of pile to bottom of layer	=	4.000000 ft
Effective unit weight at top of layer	=	110.000000 pcf
Effective unit weight at bottom of layer	=	110.000000 pcf
Friction angle at top of layer	=	25.000000 deg.
Friction angle at bottom of layer	=	25.000000 deg.
Subgrade k at top of layer	=	25.000000 pci
Subgrade k at bottom of layer	=	25.000000 pci

Layer 2 is sand, p-y criteria by Reese et al., 1974

Distance from top of pile to top of layer	=	4.000000 ft
Distance from top of pile to bottom of layer	=	11.500000 ft
Effective unit weight at top of layer	=	67.600000 pcf
Effective unit weight at bottom of layer	=	67.600000 pcf
Friction angle at top of layer	=	25.000000 deg.
Friction angle at bottom of layer	=	25.000000 deg.
Subgrade k at top of layer	=	20.000000 pci
Subgrade k at bottom of layer	=	20.000000 pci

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

Distance from top of pile to top of layer	=	11.500000 ft
Distance from top of pile to bottom of layer	=	17.000000 ft
Effective unit weight at top of layer	=	72.600000 pcf
Effective unit weight at bottom of layer	=	72.600000 pcf
Friction angle at top of layer	=	35.000000 deg.
Friction angle at bottom of layer	=	35.000000 deg.
Subgrade k at top of layer	=	125.000000 pci
Subgrade k at bottom of layer	=	125.000000 pci

Layer 4 is weak rock, p-y criteria by Reese, 1997

Distance from top of pile to top of layer	=	17.000000 ft
Distance from top of pile to bottom of layer	=	30.000000 ft
Effective unit weight at top of layer	=	77.600000 pcf
Effective unit weight at bottom of layer	=	77.600000 pcf
Uniaxial compressive strength at top of layer	=	200.000000 psi
Uniaxial compressive strength at bottom of layer	=	200.000000 psi
Initial modulus of rock at top of layer	=	1420000. psi
Initial modulus of rock at bottom of layer	=	1420000. psi
RQD of rock at top of layer	=	51.000000 %
RQD of rock at bottom of layer	=	51.000000 %
k rm of rock at top of layer	=	0.0000500
k rm of rock at bottom of layer	=	0.0000500

(Depth of the lowest soil layer extends 14.000 ft below the pile tip)

Summary of Input Soil Properties

Layer Num.	Soil Type Name or (p-y Curve Type)	Layer Depth ft	Effective Unit Wt. pcf	Angle of Friction deg.	Uniaxial qu psi	RQD %	E50 or kpy Modulus Rock Mass krm pci psi
1	Sand	0.00	110.0000	25.0000	--	--	25.0000 --
	(Reese, et al.)	4.0000	110.0000	25.0000	--	--	25.0000 --
2	Sand	4.0000	67.6000	25.0000	--	--	20.0000 --
	(Reese, et al.)	11.5000	67.6000	25.0000	--	--	20.0000 --
3	Sand	11.5000	72.6000	35.0000	--	--	125.0000 --
	(Reese, et al.)	17.0000	72.6000	35.0000	--	--	125.0000 --
4	Weak	17.0000	77.6000	--	200.0000	51.0000	5.00E-05 -- 1420000.
	Rock	30.0000	77.6000	--	200.0000	51.0000	5.00E-05 -- 1420000.

Static Loading Type

Static loading criteria were used when computing p-y curves for all analyses.

Pile-head Loading and Pile-head Fixity Conditions

Number of loads specified = 1

Load No.	Load Type	Condition 1	Condition 2	Axial Thrust Force, lbs	Compute Top y vs. Pile Length	Run Analysis
1	1	V = 1913. lbs	M = 0.0000 in-lbs	0.0000000	No	Yes

V = shear force applied normal to pile axis
M = bending moment applied to pile head
y = lateral deflection normal to pile axis
S = pile slope relative to original pile batter angle
R = rotational stiffness applied to pile head
Values of top y vs. pile lengths can be computed only for load types with specified shear loading (Load Types 1, 2, and 3).
Thrust force is assumed to be acting axially for all pile batter angles.

Computations of Nominal Moment Capacity and Nonlinear Bending Stiffness

---

Axial thrust force values were determined from pile-head loading conditions

Number of Pile Sections Analyzed = 1

Pile Section No. 1:

Dimensions and Properties of Drilled Shaft (Bored Pile):

Length of Section	=	16.000000 ft
Shaft Diameter	=	24.000000 in

Concrete Cover Thickness (to edge of long. rebar)	=	4.000000	in
Number of Reinforcing Bars	=	12	bars
Yield Stress of Reinforcing Bars	=	60000.	psi
Modulus of Elasticity of Reinforcing Bars	=	29000000.	psi
Gross Area of Shaft	=	452.389342	sq. in.
Total Area of Reinforcing Steel	=	9.480000	sq. in.
Area Ratio of Steel Reinforcement	=	2.10	percent
Edge-to-Edge Bar Spacing	=	2.882286	in
Maximum Concrete Aggregate Size	=	0.500000	in
Ratio of Bar Spacing to Aggregate Size	=	5.76	
Offset of Center of Rebar Cage from Center of Pile	=	0.0000	in

Axial Structural Capacities:

Nom. Axial Structural Capacity = 0.85 Fc Ac + Fy As	=	2074.692	kips
Tensile Load for Cracking of Concrete	=	-215.928	kips
Nominal Axial Tensile Capacity	=	-568.800	kips

Reinforcing Bar Dimensions and Positions Used in Computations:

Bar Number	Bar Diam. inches	Bar Area sq. in.	X inches	Y inches
1	1.000000	0.790000	7.500000	0.00000
2	1.000000	0.790000	6.495191	3.750000
3	1.000000	0.790000	3.750000	6.495191
4	1.000000	0.790000	0.00000	7.500000
5	1.000000	0.790000	-3.75000	6.495191
6	1.000000	0.790000	-6.49519	3.750000
7	1.000000	0.790000	-7.50000	0.00000
8	1.000000	0.790000	-6.49519	-3.75000
9	1.000000	0.790000	-3.75000	-6.49519
10	1.000000	0.790000	0.00000	-7.50000
11	1.000000	0.790000	3.750000	-6.49519
12	1.000000	0.790000	6.495191	-3.75000

NOTE: The positions of the above rebars were computed by LPile

Minimum spacing between any two bars not equal to zero = 2.882 inches
between bars 7 and 8.

Ratio of bar spacing to maximum aggregate size = 5.76

Concrete Properties:

Compressive Strength of Concrete = 4000. psi
Modulus of Elasticity of Concrete = 3604997. psi
Modulus of Rupture of Concrete = -474.34165 psi
Compression Strain at Peak Stress = 0.001886
Tensile Strain at Fracture of Concrete = -0.0001154
Maximum Coarse Aggregate Size = 0.500000 in

Number of Axial Thrust Force Values Determined from Pile-head Loadings = 1

Number	Axial Thrust Force kips
1	0.000

Definitions of Run Messages and Notes:

C = concrete in section has cracked in tension.
Y = stress in reinforcing steel has reached yield stress.
T = ACI 318 criteria for tension-controlled section met, tensile strain in reinforcement exceeds 0.005 while simultaneously compressive strain in concrete more than 0.003. See ACI 318-14, Section 21.2.3.
Z = depth of tensile zone in concrete section is less than 10 percent of section depth.

Bending Stiffness (EI) = Computed Bending Moment / Curvature.
Position of neutral axis is measured from edge of compression side of pile.
Compressive stresses and strains are positive in sign.
Tensile stresses and strains are negative in sign.

Axial Thrust Force = 0.000 kips

Bending Max Conc Curvature rad/in.	Bending Max Steel Stress ksi	Bending Moment Stress in-kip	Run Stiffness kip-in2	Depth to N Axis in	Max Comp Strain in/in	Max Tens Strain in/in	Msg
0.00000125	94.3912760	75513021.		12.0001610	0.00001500	-0.00001500	
0.0627343	0.2914558						
0.00000250	188.3222133	75328885.		12.0001616	0.00003000	-0.00003000	
0.1249728	0.5829117						
0.00000375	281.7928118	75144750.		12.0001622	0.00004500	-0.00004500	
0.1867155	0.8743676						
0.00000500	374.8030716	74960614.		12.0001627	0.00006000	-0.00006000	

```
 0.2479623     1.1658236
0.00000625   467.3529926     74776479.    12.0001633    0.00007500   -0.00007500
 0.3087133     1.4572796
0.00000750   559.4425749     74592343.    12.0001639    0.00009000   -0.00009000
 0.3689684     1.7487357
0.00000875   651.0718185     74408208.    12.0001645     0.0001050    -0.000105
 0.4287278     2.0401918
0.00001000   651.0718185     65107182.     7.0895135    0.00007090    -0.000169
 0.2901283    -3.755641 C
0.00001125   651.0718185     57873051.     7.0920465    0.00007979    -0.000190
 0.3257422    -4.224270 C
0.00001250   651.0718185     52085745.     7.0945856    0.00008868    -0.000211
 0.3612103    -4.692713 C
0.00001375   651.0718185     47350678.     7.0971310    0.00009759    -0.000232
 0.3965323    -5.160969 C
0.00001500   651.0718185     43404788.     7.0996827     0.0001065    -0.000254
 0.4317079    -5.629038 C
0.00001625   651.0718185     40065958.     7.1022407     0.0001154    -0.000275
 0.4667368    -6.096919 C
0.00001750   651.0718185     37204104.     7.1048050     0.0001243    -0.000296
 0.5016187    -6.564611 C
0.00001875   651.0718185     34723830.     7.1073758     0.0001333    -0.000317
 0.5363533    -7.032114 C
0.00002000   651.0718185     32553591.     7.1099529     0.0001422    -0.000338
 0.5709404    -7.499427 C
0.00002125   651.0718185     30638674.     7.1125365     0.0001511    -0.000359
 0.6053796    -7.966549 C
0.00002250   651.0718185     28936525.     7.1151266     0.0001601    -0.000380
 0.6396707    -8.433480 C
0.00002375   651.0718185     27413550.     7.1177232     0.0001690    -0.000401
 0.6738134    -8.900218 C
0.00002500   651.0718185     26042873.     7.1203263     0.0001780    -0.000422
 0.7078073    -9.366763 C
0.00002625   651.0718185     24802736.     7.1229361     0.0001870    -0.000443
 0.7416522    -9.833115 C
0.00002750   651.0718185     23675339.     7.1255524     0.0001960    -0.000464
 0.7753477   -10.299272 C
0.00002875   651.0718185     22645976.     7.1281754     0.0002049    -0.000485
 0.8088937   -10.765234 C
0.00003000   651.0718185     21702394.     7.1308051     0.0002139    -0.000506
 0.8422897   -11.230999 C
0.00003125   651.0718185     20834298.     7.1334415     0.0002229    -0.000527
 0.8755354   -11.696569 C
0.00003250   651.0718185     20032979.     7.1360847     0.0002319    -0.000548
 0.9086306   -12.161940 C
0.00003375   668.2431395     19799797.     7.1387346     0.0002409    -0.000569
 0.9415750   -12.627113 C
0.00003500   692.6630973     19790374.     7.1413914     0.0002499    -0.000590
 0.9743682   -13.092088 C
0.00003625   717.0587367     19780931.     7.1440550     0.0002590    -0.000611
```

```
 1.0070099    -13.556862 C
0.00003750   741.4299750     19771466.     7.1467256     0.0002680     -0.000632
 1.0394998    -14.021436 C
0.00003875   765.7767291     19761980.     7.1494031     0.0002770     -0.000653
 1.0718376    -14.485808 C
0.00004000   790.0989150     19752473.     7.1520875     0.0002861     -0.000674
 1.1040230    -14.949978 C
0.00004125   814.3964486     19742944.     7.1547790     0.0002951     -0.000695
 1.1360556    -15.413946 C
0.00004250   838.6692449     19733394.     7.1574775     0.0003042     -0.000716
 1.1679352    -15.877709 C
0.00004375   862.9172184     19723822.     7.1601831     0.0003133     -0.000737
 1.1996614    -16.341268 C
0.00004500   887.1402832     19714229.     7.1628958     0.0003223     -0.000758
 1.2312339    -16.804621 C
0.00004625   911.3383526     19704613.     7.1656157     0.0003314     -0.000779
 1.2626523    -17.267768 C
0.00004750   935.5113395     19694976.     7.1683427     0.0003405     -0.000800
 1.2939164    -17.730708 C
0.00004875   959.6591560     19685316.     7.1710770     0.0003496     -0.000820
 1.3250258    -18.193440 C
0.00005125        1008.      19665930.     7.1765675     0.0003678     -0.000862
 1.3867791    -19.118276 C
0.00005375        1056.      19646455.     7.1820875     0.0003860     -0.000904
 1.4479097    -20.042271 C
0.00005625        1104.      19626889.     7.1876372     0.0004043     -0.000946
 1.5084148    -20.965417 C
0.00005875        1152.      19607231.     7.1932169     0.0004226     -0.000987
 1.5682916    -21.887707 C
0.00006125        1200.      19587481.     7.1988271     0.0004409     -0.001029
 1.6275373    -22.809133 C
0.00006375        1247.      19567638.     7.2044680     0.0004593     -0.001071
 1.6861492    -23.729690 C
0.00006625        1295.      19547700.     7.2101401     0.0004777     -0.001112
 1.7441245    -24.649368 C
0.00006875        1343.      19527666.     7.2158436     0.0004961     -0.001154
 1.8014601    -25.568162 C
0.00007125        1390.      19507537.     7.2215789     0.0005145     -0.001195
 1.8581533    -26.486062 C
0.00007375        1437.      19487310.     7.2273464     0.0005330     -0.001237
 1.9142010    -27.403063 C
0.00007625        1484.      19466984.     7.2331464     0.0005515     -0.001278
 1.9696002    -28.319155 C
0.00007875        1531.      19446559.     7.2389793     0.0005701     -0.001320
 2.0243480    -29.234331 C
0.00008125        1578.      19426034.     7.2448456     0.0005886     -0.001361
 2.0784413    -30.148582 C
0.00008375        1625.      19405406.     7.2507456     0.0006072     -0.001403
 2.1318768    -31.061901 C
0.00008625        1672.      19384676.     7.2566796     0.0006259     -0.001444
```

 2.1846516   -31.974280 C
0.00008875   1719.   19363842.   7.2626481   0.0006446   -0.001485
 2.2367624   -32.885709 C
0.00009125   1765.   19342903.   7.2686516   0.0006633   -0.001527
 2.2882060   -33.796180 C
0.00009375   1811.   19321858.   7.2746903   0.0006820   -0.001568
 2.3389790   -34.705685 C
0.00009625   1858.   19300705.   7.2807649   0.0007008   -0.001609
 2.3890782   -35.614215 C
0.00009875   1904.   19279444.   7.2868756   0.0007196   -0.001650
 2.4385002   -36.521760 C
 0.0001013   1950.   19258072.   7.2930229   0.0007384   -0.001692
 2.4872416   -37.428311 C
 0.0001038   1996.   19236590.   7.2992073   0.0007573   -0.001733
 2.5352989   -38.333860 C
 0.0001063   2042.   19214995.   7.3054293   0.0007762   -0.001774
 2.5826687   -39.238396 C
 0.0001088   2087.   19193286.   7.3116892   0.0007951   -0.001815
 2.6293473   -40.141910 C
 0.0001113   2133.   19171462.   7.3179876   0.0008141   -0.001856
 2.6753312   -41.044392 C
 0.0001138   2178.   19149550.   7.3241825   0.0008331   -0.001897
 2.7205777   -41.946303 C
 0.0001163   2224.   19127536.   7.3303481   0.0008522   -0.001938
 2.7651031   -42.847414 C
 0.0001188   2269.   19105407.   7.3365511   0.0008712   -0.001979
 2.8089215   -43.747502 C
 0.0001213   2314.   19083162.   7.3427920   0.0008903   -0.002020
 2.8520293   -44.646557 C
 0.0001238   2359.   19060800.   7.3490712   0.0009094   -0.002061
 2.8944227   -45.544570 C
 0.0001263   2404.   19038318.   7.3553892   0.0009286   -0.002101
 2.9360979   -46.441531 C
 0.0001288   2448.   19015716.   7.3617466   0.0009478   -0.002142
 2.9770511   -47.337428 C
 0.0001313   2493.   18992993.   7.3681437   0.0009671   -0.002183
 3.0172784   -48.232253 C
 0.0001338   2537.   18970146.   7.3745812   0.0009864   -0.002224
 3.0567757   -49.125993 C
 0.0001363   2582.   18947174.   7.3810596   0.0010057   -0.002264
 3.0955391   -50.018638 C
 0.0001388   2626.   18924076.   7.3875793   0.0010250   -0.002305
 3.1335644   -50.910177 C
 0.0001413   2670.   18900850.   7.3941411   0.0010444   -0.002346
 3.1708476   -51.800599 C
 0.0001438   2714.   18877495.   7.4007453   0.0010639   -0.002386
 3.2073843   -52.689893 C
 0.0001463   2757.   18854009.   7.4073926   0.0010833   -0.002427
 3.2431704   -53.578046 C
 0.0001488   2801.   18830390.   7.4140836   0.0011028   -0.002467

```
3.2782014    -54.465046 C
0.0001588         2974.     18734553.     7.4412964     0.0011813     -0.002629
3.4106856    -58.001281 C
0.0001688         3144.     18628437.     7.4681982     0.0012603     -0.002790
3.5304632    -60.000000 CY
0.0001788         3292.     18417289.     7.4816603     0.0013373     -0.002953
3.6342608    -60.000000 CY
0.0001888         3413.     18084564.     7.4775119     0.0014114     -0.003119
3.7217028    -60.000000 CY
0.0001988         3497.     17592713.     7.4477312     0.0014802     -0.003290
3.7922432    -60.000000 CY
0.0002088         3570.     17102814.     7.4167826     0.0015483     -0.003462
3.8518073    -60.000000 CY
0.0002188         3643.     16652143.     7.3909242     0.0016168     -0.003633
3.9016624    -60.000000 CY
0.0002288         3714.     16235380.     7.3695705     0.0016858     -0.003804
3.9415935    -60.000000 CY
0.0002388         3782.     15839155.     7.3503549     0.0017549     -0.003975
3.9712114    -60.000000 CY
0.0002488         3834.     15414182.     7.3226596     0.0018215     -0.004148
3.9899372    -60.000000 CY
0.0002588         3870.     14955602.     7.2830376     0.0018845     -0.004326
3.9987879    -60.000000 CY
0.0002688         3898.     14504756.     7.2421848     0.0019463     -0.004504
3.9984871    -60.000000 CY
0.0002788         3925.     14082272.     7.2057303     0.0020086     -0.004681
3.9977312    -60.000000 CY
0.0002888         3952.     13686075.     7.1734635     0.0020713     -0.004859
3.9962952    -60.000000 CY
0.0002988         3977.     13313600.     7.1449562     0.0021346     -0.005035
3.9999920    -60.000000 CY
0.0003088         4002.     12962501.     7.1198892     0.0021983     -0.005212
3.9994825    -60.000000 CY
0.0003188         4026.     12631049.     7.0978405     0.0022624     -0.005388
3.9977653    -60.000000 CY
0.0003288         4049.     12317614.     7.0783772     0.0023270     -0.005563
3.9978694    -60.000000 CY
0.0003388         4072.     12020306.     7.0605074     0.0023917     -0.005738
3.9994066    -60.000000 CY
0.0003488         4094.     11738246.     7.0449332     0.0024569     -0.005913
3.9963345    -60.000000 CY
0.0003588         4115.     11470313.     7.0313942     0.0025225     -0.006087
3.9998984    -60.000000 CY
0.0003688         4136.     11215201.     7.0198370     0.0025886     -0.006261
3.9971944    -60.000000 CY
0.0003788         4156.     10972130.     7.0097695     0.0026550     -0.006435
3.9999823    -60.000000 CY
0.0003888         4174.     10737994.     7.0003740     0.0027214     -0.006609
3.9970500    -60.000000 CY
0.0003988         4190.     10508927.     6.9893271     0.0027870     -0.006783
```

```
    3.9999202    -60.000000 CY
    0.0004088         4204.     10283865.     6.9764958     0.0028516     -0.006958
    3.9952971    -60.000000 CY
    0.0004188         4215.     10064652.     6.9626196     0.0029156     -0.007134
    3.9992445    -60.000000 CY
    0.0004288         4222.      9847056.     6.9453771     0.0029778     -0.007312
    3.9965169    -60.000000 CY
    0.0004388         4228.      9637072.     6.9285964     0.0030399     -0.007490
    3.9963090    -60.000000 CYT
    0.0004488         4232.      9430126.     6.9092170     0.0031005     -0.007669
    3.9993356    -60.000000 CYT
    0.0004588         4235.      9231653.     6.8910223     0.0031613     -0.007849
    3.9972298    -60.000000 CYT
    0.0004688         4238.      9041089.     6.8740748     0.0032222     -0.008028
    3.9944442    -60.000000 CYT
    0.0004788         4241.      8858275.     6.8581617     0.0032833     -0.008207
    3.9982746    -60.000000 CYT
    0.0004888         4244.      8682730.     6.8432265     0.0033446     -0.008385
    3.9999299    -60.000000 CYT
    0.0004988         4246.      8513678.     6.8284705     0.0034057     -0.008564
    3.9927329    -60.000000 CYT
    0.0005088         4249.      8351012.     6.8143716     0.0034668     -0.008743
    3.9948307    -60.000000 CYT
    0.0005188         4251.      8194468.     6.8010897     0.0035281     -0.008922
    3.9982940    -60.000000 CYT
    0.0005288         4253.      8043697.     6.7885840     0.0035895     -0.009101
    3.9998885    -60.000000 CYT
    0.0005388         4255.      7898253.     6.7769862     0.0036511     -0.009279
    3.9939551    -60.000000 CYT
    0.0005488         4257.      7757930.     6.7661287     0.0037129     -0.009457
    3.9922538    -60.000000 CYT
    0.0006088         4257.      6993288.     6.7655260     0.0041185     -0.010491
    3.9988266    -60.000000 CYT


--------------------------------------------------------------------------------
   Summary of Results for Nominal Moment Capacity for Section 1
--------------------------------------------------------------------------------

Moment values interpolated at maximum compressive strain = 0.003
or maximum developed moment if pile fails at smaller strains.

 Load           Axial Thrust        Nominal Mom. Cap.      Max. Comp.      Max.
Tens.
  No.              kips                 in-kip               Strain
Strain
 ----         ---------------     ------------------     ------------
------------
   1                0.000             4224.189          0.00300000
-0.00737569
```

Note that the values of moment capacity in the table above are not factored by a strength reduction factor (phi-factor).

In ACI 318, the value of the strength reduction factor depends on whether the transverse reinforcing steel bars are tied hoops (0.65) or spirals (0.75).

The above values should be multiplied by the appropriate strength reduction factor to compute ultimate moment capacity according to ACI 318, or the value required by the design standard being followed.

The following table presents factored moment capacities and corresponding bending stiffnesses computed for common resistance factor values used for reinforced concrete sections.

Axial Load No.	Resist. Factor	Nominal Ax. Thrust kips	Nominal Moment Cap in-kips	Ult. (Fac) Ax. Thrust kips	Ult. (Fac) Moment Cap in-kips	Bend. Stiff. at Ult Mom kip-in^2
1	0.65	0.0000	4224.	0.0000	2746.	18860275.
1	0.75	0.0000	4224.	0.0000	3168.	18593479.
1	0.90	0.0000	4224.	0.0000	3802.	15676426.

Layering Correction Equivalent Depths of Soil & Rock Layers

Layer No.	Top of Layer Below Pile Head ft	Equivalent Top Depth Below Grnd Surf ft	Same Layer Type As Layer Above	Layer is Rock or is Below Rock Layer	F0 Integral for Layer lbs	F1 Integral for Layer lbs
1	0.00	0.00	N.A.	No	0.00	11790.
2	4.0000	4.0000	Yes	No	11790.	69203.
3	11.5000	8.6139	Yes	No	80993.	137183.
4	17.0000	17.0000	No	Yes	N.A.	N.A.

Notes: The F0 integral of Layer n+1 equals the sum of the F0 and F1 integrals

for Layer n. Layering correction equivalent depths are computed only for soil types with both shallow-depth and deep-depth expressions for peak lateral load transfer. These soil types are soft and stiff clays, non-liquefied sands, and cemented c-phi soil.

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

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

Shear force at pile head = 1913.2 lbs
Applied moment at pile head = 0.0 in-lbs
Axial thrust load on pile head = 0.0 lbs

Depth X	Deflect. y	Bending Moment	Shear Force	Slope S	Total Stress	Bending Stiffness	Soil Res. Es*H	Soil Spr. Lat. Load	Distrib. p
feet	inches	in-lbs	lbs	radians	psi*	lb-in^2	lb/inch	lb/inch	lb/inch
0.00	0.03986	1.71E-06	1913.	-3.17E-04	0.00	7.55E+10	0.00	0.00	0.00
0.1600	0.03926	3673.	1911.	-3.16E-04	0.00	7.55E+10	-1.884	92.1600	0.00
0.3200	0.03865	7340.	1906.	-3.16E-04	0.00	7.55E+10	-3.710	184.3200	0.00
0.4800	0.03804	10993.	1897.	-3.16E-04	0.00	7.55E+10	-5.478	276.4800	0.00
0.6400	0.03744	14625.	1885.	-3.16E-04	0.00	7.55E+10	-7.188	368.6400	0.00
0.8000	0.03683	18231.	1870.	-3.15E-04	0.00	7.55E+10	-8.839	460.8000	0.00
0.9600	0.03622	21805.	1851.	-3.15E-04	0.00	7.55E+10	-10.433	552.9600	0.00
1.1200	0.03562	25340.	1830.	-3.14E-04	0.00	7.55E+10	-11.968	645.1200	0.00
1.2800	0.03502	28831.	1805.	-3.14E-04	0.00	7.55E+10	-13.447	737.2800	0.00
1.4400	0.03442	32272.	1778.	-3.13E-04	0.00	7.55E+10	-14.868	829.4400	0.00
1.6000	0.03382	35659.	1748.	-3.12E-04	0.00	7.55E+10	-16.232	921.6000	0.00
1.7600	0.03322	38986.	1716.	-3.11E-04	0.00	7.55E+10			

-17.539 1014. 0.00
1.9200 0.03262 42248. 1681. -3.10E-04 0.00 7.55E+10
-18.791 1106. 0.00
2.0800 0.03203 45441. 1644. -3.09E-04 0.00 7.55E+10
-19.986 1198. 0.00
2.2400 0.03144 48560. 1604. -3.08E-04 0.00 7.55E+10
-21.125 1290. 0.00
2.4000 0.03085 51601. 1563. -3.06E-04 0.00 7.55E+10
-22.210 1382. 0.00
2.5600 0.03026 54560. 1519. -3.05E-04 0.00 7.55E+10
-23.240 1475. 0.00
2.7200 0.02968 57434. 1473. -3.04E-04 0.00 7.55E+10
-24.215 1567. 0.00
2.8800 0.02909 60219. 1426. -3.02E-04 0.00 7.55E+10
-25.137 1659. 0.00
3.0400 0.02852 62910. 1377. -3.01E-04 0.00 7.55E+10
-26.006 1751. 0.00
3.2000 0.02794 65506. 1326. -2.99E-04 0.00 7.55E+10
-26.823 1843. 0.00
3.3600 0.02737 68003. 1274. -2.97E-04 0.00 7.55E+10
-27.587 1935. 0.00
3.5200 0.02680 70399. 1220. -2.95E-04 0.00 7.55E+10
-28.300 2028. 0.00
3.6800 0.02623 72690. 1165. -2.94E-04 0.00 7.55E+10
-28.962 2120. 0.00
3.8400 0.02567 74874. 1109. -2.92E-04 0.00 7.55E+10
-29.573 2212. 0.00
4.0000 0.02511 76949. 1058. -2.90E-04 0.00 7.55E+10
-24.109 1843. 0.00
4.1600 0.02456 78936. 1011. -2.88E-04 0.00 7.55E+10
-24.519 1917. 0.00
4.3200 0.02401 80832. 963.5910 -2.86E-04 0.00 7.55E+10
-24.891 1991. 0.00
4.4800 0.02346 82636. 915.4793 -2.84E-04 0.00 7.55E+10
-25.225 2064. 0.00
4.6400 0.02292 84347. 866.7622 -2.82E-04 0.00 7.55E+10
-25.522 2138. 0.00
4.8000 0.02238 85964. 817.5113 -2.79E-04 0.00 7.55E+10
-25.781 2212. 0.00
4.9600 0.02185 87486. 767.7970 -2.77E-04 0.00 7.55E+10
-26.004 2286. 0.00
5.1200 0.02132 88913. 717.6885 -2.75E-04 0.00 7.55E+10
-26.192 2359. 0.00
5.2800 0.02079 90242. 667.2540 -2.73E-04 0.00 7.55E+10
-26.344 2433. 0.00
5.4400 0.02027 91475. 616.5606 -2.70E-04 0.00 7.55E+10
-26.462 2507. 0.00
5.6000 0.01975 92610. 565.6741 -2.68E-04 0.00 7.55E+10
-26.545 2580. 0.00
5.7600 0.01924 93647. 514.6594 -2.66E-04 0.00 7.55E+10

-26.595 2654. 0.00
5.9200 0.01873 94586. 463.5802 -2.63E-04 0.00 7.55E+10
-26.612 2728. 0.00
6.0800 0.01823 95427. 412.4990 -2.61E-04 0.00 7.55E+10
-26.597 2802. 0.00
6.2400 0.01773 96170. 361.4770 -2.58E-04 0.00 7.55E+10
-26.551 2875. 0.00
6.4000 0.01723 96815. 310.5747 -2.56E-04 0.00 7.55E+10
-26.473 2949. 0.00
6.5600 0.01675 97363. 259.8510 -2.54E-04 0.00 7.55E+10
-26.364 3023. 0.00
6.7200 0.01626 97813. 209.3640 -2.51E-04 0.00 7.55E+10
-26.226 3097. 0.00
6.8800 0.01578 98167. 159.1704 -2.49E-04 0.00 7.55E+10
-26.059 3170. 0.00
7.0400 0.01531 98424. 109.3261 -2.46E-04 0.00 7.55E+10
-25.862 3244. 0.00
7.2000 0.01484 98586. 59.8857 -2.44E-04 0.00 7.55E+10
-25.638 3318. 0.00
7.3600 0.01437 98654. 10.9027 -2.41E-04 0.00 7.55E+10
-25.386 3391. 0.00
7.5200 0.01391 98628. -37.571 -2.39E-04 0.00 7.55E+10
-25.107 3465. 0.00
7.6800 0.01346 98510. -85.483 -2.36E-04 0.00 7.55E+10
-24.801 3539. 0.00
7.8400 0.01300 98300. -132.783 -2.34E-04 0.00 7.55E+10
-24.470 3613. 0.00
8.0000 0.01256 98000. -179.423 -2.31E-04 0.00 7.55E+10
-24.113 3686. 0.00
8.1600 0.01212 97611. -225.353 -2.29E-04 0.00 7.55E+10
-23.731 3760. 0.00
8.3200 0.01168 97135. -270.528 -2.26E-04 0.00 7.55E+10
-23.325 3834. 0.00
8.4800 0.01125 96572. -314.899 -2.24E-04 0.00 7.55E+10
-22.895 3908. 0.00
8.6400 0.01082 95925. -358.423 -2.21E-04 0.00 7.55E+10
-22.442 3981. 0.00
8.8000 0.01040 95196. -401.054 -2.19E-04 0.00 7.55E+10
-21.966 4055. 0.00
8.9600 0.00998 94385. -442.749 -2.16E-04 0.00 7.55E+10
-21.467 4129. 0.00
9.1200 0.00957 93496. -483.466 -2.14E-04 0.00 7.55E+10
-20.946 4202. 0.00
9.2800 0.00916 92529. -523.162 -2.12E-04 0.00 7.55E+10
-20.404 4276. 0.00
9.4400 0.00876 91487. -561.797 -2.09E-04 0.00 7.55E+10
-19.841 4350. 0.00
9.6000 0.00836 90372. -599.330 -2.07E-04 0.00 7.55E+10
-19.256 4424. 0.00
9.7600 0.00796 89185. -635.722 -2.05E-04 0.00 7.55E+10

```
-18.652      4497.       0.00
    9.9200    0.00757     87930.   -670.934  -2.02E-04       0.00   7.55E+10
-18.028      4571.       0.00
   10.0800    0.00719     86609.   -704.929  -2.00E-04       0.00   7.55E+10
-17.384      4645.       0.00
   10.2400    0.00680     85224.   -737.669  -1.98E-04       0.00   7.55E+10
-16.720      4719.       0.00
   10.4000    0.00643     83776.   -769.116  -1.96E-04       0.00   7.55E+10
-16.038      4792.       0.00
   10.5600    0.00605     82270.   -799.236  -1.94E-04       0.00   7.55E+10
-15.337      4866.       0.00
   10.7200    0.00568     80707.   -827.993  -1.92E-04       0.00   7.55E+10
-14.618      4940.       0.00
   10.8800    0.00532     79091.   -855.350  -1.90E-04       0.00   7.55E+10
-13.880      5014.       0.00
   11.0400    0.00495     77423.   -881.275  -1.88E-04       0.00   7.55E+10
-13.125      5087.       0.00
   11.2000    0.00460     75707.   -905.732  -1.86E-04       0.00   7.55E+10
-12.352      5161.       0.00
   11.3600    0.00424     73945.   -928.689  -1.84E-04       0.00   7.55E+10
-11.561      5235.       0.00
   11.5200    0.00389     72140.     -1004.  -1.82E-04       0.00   7.55E+10
-67.210     33178.       0.00
   11.6800    0.00354     70088.     -1128.  -1.80E-04       0.00   7.55E+10
-62.055     33638.       0.00
   11.8400    0.00320     67807.     -1242.  -1.78E-04       0.00   7.55E+10
-56.794     34099.       0.00
   12.0000    0.00286     65317.     -1346.  -1.77E-04       0.00   7.55E+10
-51.427     34560.       0.00
   12.1600    0.00252     62637.     -1440.  -1.75E-04       0.00   7.55E+10
-45.955     35021.       0.00
   12.3200    0.00218     59788.     -1523.  -1.73E-04       0.00   7.55E+10
-40.378     35482.       0.00
   12.4800    0.00185     56790.     -1595.  -1.72E-04       0.00   7.55E+10
-34.694     35942.       0.00
   12.6400    0.00152     53664.     -1656.  -1.71E-04       0.00   7.55E+10
-28.904     36403.       0.00
   12.8000    0.00120     50431.     -1706.  -1.69E-04       0.00   7.55E+10
-23.006     36864.       0.00
   12.9600   8.74E-04     47114.     -1744.  -1.68E-04       0.00   7.55E+10
-17.000     37325.       0.00
   13.1200   5.53E-04     43734.     -1771.  -1.67E-04       0.00   7.55E+10
-10.884     37786.       0.00
   13.2800   2.34E-04     40314.     -1786.  -1.66E-04       0.00   7.55E+10
-4.655      38246.       0.00
   13.4400  -8.37E-05     36876.     -1789.  -1.65E-04       0.00   7.55E+10
1.6867      38707.       0.00
   13.6000  -3.99E-04     33445.     -1779.  -1.64E-04       0.00   7.55E+10
8.1442      39168.       0.00
   13.7600  -7.13E-04     30044.     -1757.  -1.63E-04       0.00   7.55E+10
```

```
14.7194     39629.       0.00
   13.9200   -0.00103     26697.     -1723.  -1.62E-04       0.00   7.55E+10
21.4148     40090.       0.00
   14.0800   -0.00134     23429.     -1675.  -1.62E-04       0.00   7.55E+10
28.2325     40550.       0.00
   14.2400   -0.00165     20266.     -1614.  -1.61E-04       0.00   7.55E+10
35.1752     41011.       0.00
   14.4000   -0.00196     17231.     -1540.  -1.61E-04       0.00   7.55E+10
42.2454     41472.       0.00
   14.5600   -0.00226     14353.     -1452.  -1.60E-04       0.00   7.55E+10
49.4455     41933.       0.00
   14.7200   -0.00257     11657.     -1350.  -1.60E-04       0.00   7.55E+10
56.7780     42394.       0.00
   14.8800   -0.00288      9170.     -1234.  -1.60E-04       0.00   7.55E+10
64.2455     42854.       0.00
   15.0400   -0.00318      6920.     -1103.  -1.60E-04       0.00   7.55E+10
71.8502     43315.       0.00
   15.2000   -0.00349      4935.   -957.504  -1.59E-04       0.00   7.55E+10
79.5942     43776.       0.00
   15.3600   -0.00380      3243.   -797.113  -1.59E-04       0.00   7.55E+10
87.4797     44237.       0.00
   15.5200   -0.00410      1874.   -621.444  -1.59E-04       0.00   7.55E+10
95.5083     44698.       0.00
   15.6800   -0.00441   856.9629   -430.222  -1.59E-04       0.00   7.55E+10
103.6815     45158.       0.00
   15.8400   -0.00471   222.0424   -223.167  -1.59E-04       0.00   7.55E+10
112.0004     45619.       0.00
   16.0000   -0.00502       0.00       0.00  -1.59E-04       0.00   7.55E+10
120.4657     23040.       0.00
```

* This analysis computed pile response using nonlinear moment-curvature relationships. Values of total stress due to combined axial and bending stresses are computed only for elastic sections only and do not equal the actual stresses in concrete and steel. Stresses in concrete and steel may be interpolated from the output for nonlinear bending properties relative to the magnitude of bending moment developed in the pile.

Output Summary for Load Case No. 1:

```
Pile-head deflection             =     0.03986473 inches
Computed slope at pile head      =     -0.0003165 radians
Maximum bending moment           =         98654. inch-lbs
Maximum shear force              =          1913. lbs
Depth of maximum bending moment  =     7.36000000 feet below pile head
Depth of maximum shear force     =       0.000000 feet below pile head
Number of iterations             =              6
Number of zero deflection points =              1
```

```
--------------------------------------------------------------------------------
            Summary of Pile-head Responses for Conventional Analyses
--------------------------------------------------------------------------------

Definitions of Pile-head Loading Conditions:

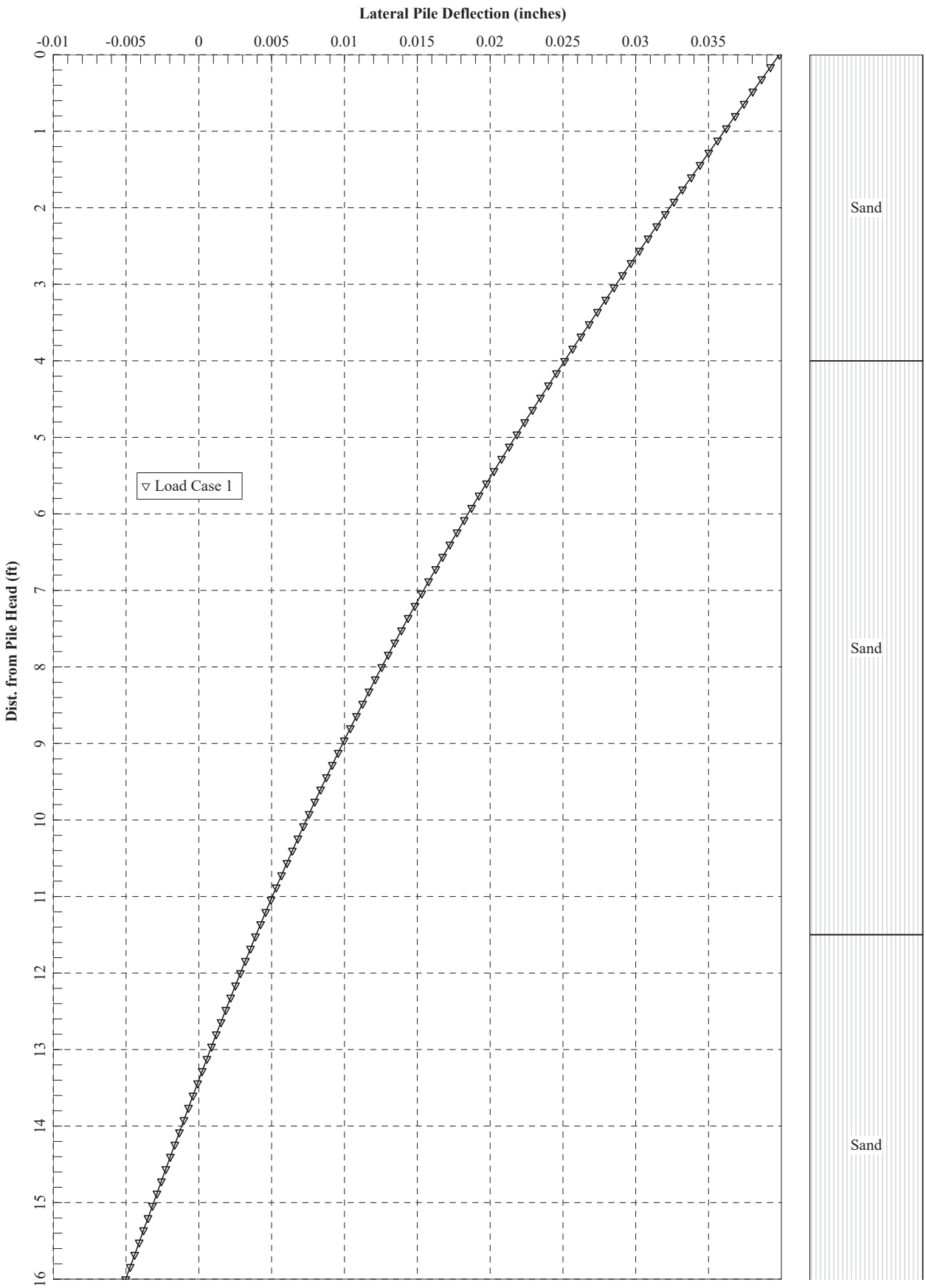
Load Type 1: Load 1 = Shear, V, lbs, and Load 2 = Moment, M, in-lbs
Load Type 2: Load 1 = Shear, V, lbs, and Load 2 = Slope, S, radians
Load Type 3: Load 1 = Shear, V, lbs, and Load 2 = Rot. Stiffness, R, in-lbs/rad.
Load Type 4: Load 1 = Top Deflection, y, inches, and Load 2 = Moment, M, in-lbs
Load Type 5: Load 1 = Top Deflection, y, inches, and Load 2 = Slope, S, radians

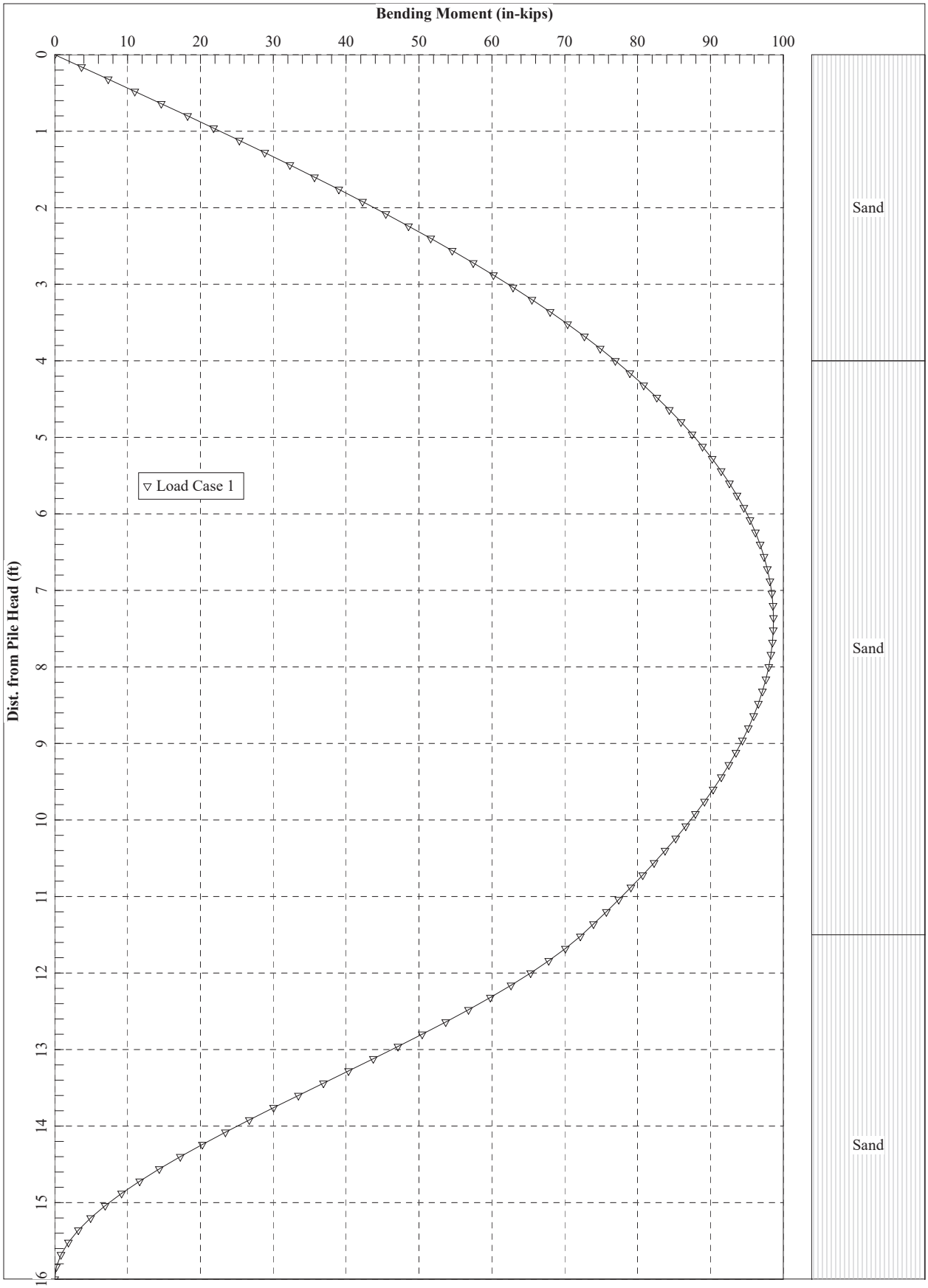

Load Load                Load                  Axial    Pile-head  Pile-head  Max
Shear Max Moment
Case Type   Pile-head    Type     Pile-head   Loading  Deflection  Rotation    in
Pile    in Pile
 No.  1      Load 1       2        Load 2       lbs      inches     radians
lbs      in-lbs
---- ----- ---------- ---------- ---------- ---------- ---------- ----------
---------- ----------
  1  V, lb      1913.  M, in-lb        0.00       0.00    0.03986  -3.17E-04
1913.     98654.

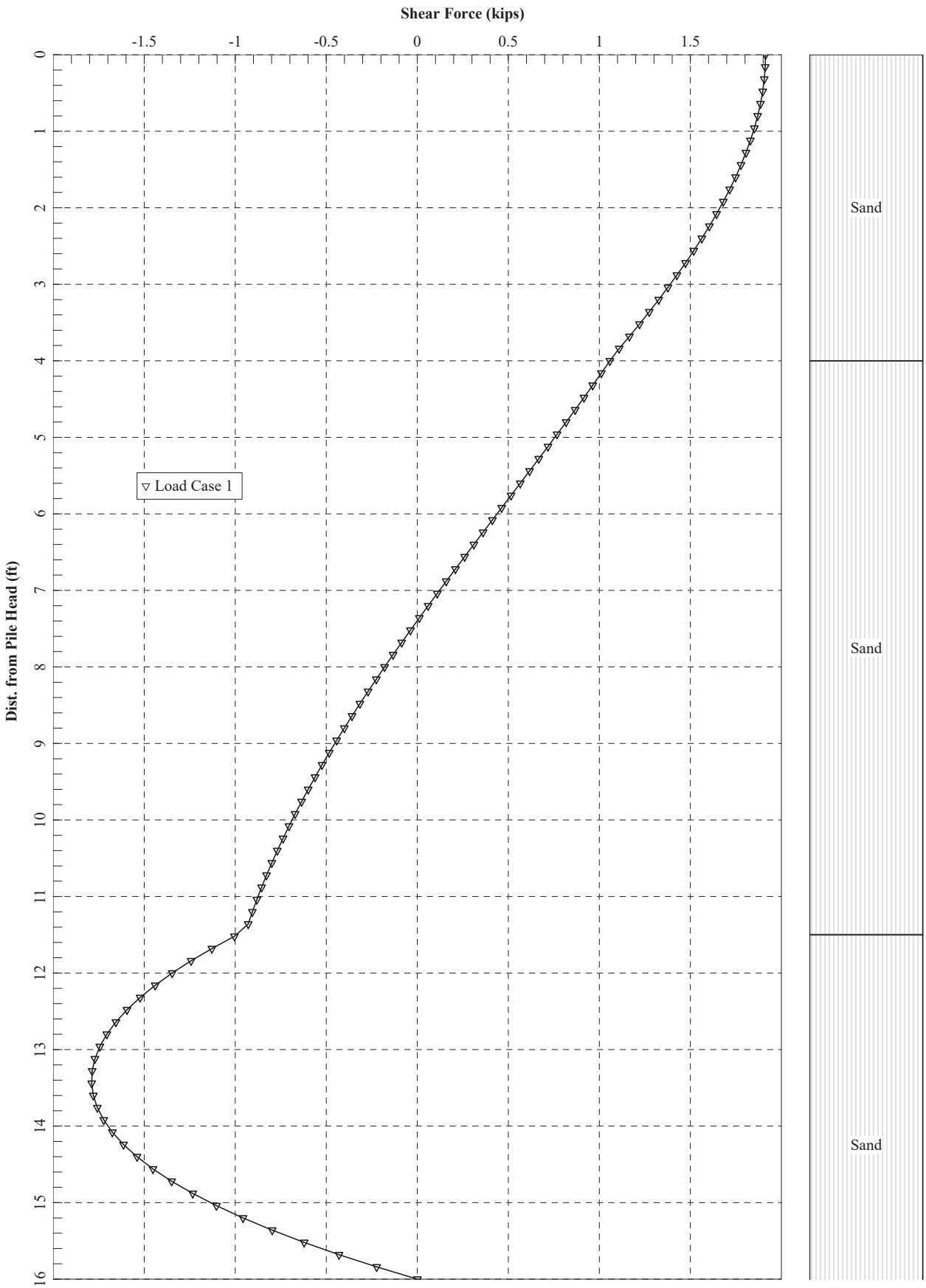

Maximum pile-head deflection = 0.0398647316 inches
Maximum pile-head rotation   = -0.0003165347 radians = -0.018136 deg.

The analysis ended normally.
```

STR-I Load Case Anticipated Deflection (Caisson Bearing in Residual Soil) = 0.04 inches


Lateral Pile Deflection (inches)
-0.01
-0.005
0
0.005
0.01
0.015
0.02
0.025
0.03
0.035
Dist. from Pile Head (ft)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
Load Case 1
Sand
Sand
Sand


Bending Moment (in-kips)
0
10
20
30
40
50
60
70
80
90
100
Dist. from Pile Head (ft)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
Load Case 1
Sand
Sand
Sand


Shear Force (kips)
-1.5
-1
-0.5
0
0.5
1
1.5
Dist. from Pile Head (ft)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
Load Case 1
Sand
Sand
Sand

SER-I Load Case Results
Caisson Bearing in Claystone Bedrock

==========

LPile for Windows, Version 2022-12.009

Analysis of Individual Piles and Drilled Shafts
Subjected to Lateral Loading Using the p-y Method
© 1985-2022 by Ensoft, Inc.
All Rights Reserved

==========

By: SMC 07/23
Checked by: RHY 08/23

This copy of LPile is being used by:

Gannett Fleming, Inc
Pittsburgh, PA

Serial Number of Security Device: 546957815

This copy of LPile is licensed for exclusive use by:

Gannett Fleming, Inc., LPILE Sm Global, SmGlobal Licens

Use of this software by employees of Gannett Fleming, Inc.
other than those of the office site in LPILE Sm Global, SmGlobal Licens
is a violation of the software license agreement.

Files Used for Analysis

Path to file locations:
\Users\schechak\Desktop\SR88 Grade Crossing\

Name of input data file:
SR88 Grade Crossing Caisson (SER-I Load Case).lp12d

Name of output report file:
SR88 Grade Crossing Caisson (SER-I Load Case).lp12o

Name of plot output file:
SR88 Grade Crossing Caisson (SER-I Load Case).lp12p

Name of runtime message file:
SR88 Grade Crossing Caisson (SER-I Load Case).lp12r

Date and Time of Analysis

Date: July 28, 2023 Time: 11:48:38

Problem Title

Project Name: SR88 Grade Crossing Gate Foundation

Job Number: 073937.06

Client: Port Authority of Allegheny County

Engineer: S. Chechak

Description:

Program Options and Settings

Computational Options:
- Conventional Analysis

Engineering Units Used for Data Input and Computations:
- US Customary System Units (pounds, feet, inches)

Analysis Control Options:

- Maximum number of iterations allowed	=	500
- Deflection tolerance for convergence	=	1.0000E-05 in
- Maximum allowable deflection	=	100.0000 in
- Number of pile increments	=	100

Loading Type and Number of Cycles of Loading:
- Static loading specified

- Use of p-y modification factors for p-y curves not selected
- Analysis uses layering correction (Method of Georgiadis)
- No distributed lateral loads are entered
- Loading by lateral soil movements acting on pile not selected
- Input of shear resistance at the pile tip not selected
- Input of moment resistance at the pile tip not selected
- Computation of pile-head foundation stiffness matrix not selected
- Push-over analysis of pile not selected
- Buckling analysis of pile not selected

Output Options:
- Output files use decimal points to denote decimal symbols.
- Values of pile-head deflection, bending moment, shear force, and soil reaction are printed for full length of pile.
- Printing Increment (nodal spacing of output points) = 1
- No p-y curves to be computed and reported for user-specified depths
- Print using wide report formats

Pile Structural Properties and Geometry

Number of pile sections defined = 1
Total length of pile = 20.000 ft
Depth of ground surface below top of pile = 0.0000 ft

Pile diameters used for p-y curve computations are defined using 2 points.

p-y curves are computed using pile diameter values interpolated with depth over the length of the pile. A summary of values of pile diameter vs. depth follows.

Point No.	Depth Below Pile Head feet	Pile Diameter inches
1	0.000	24.0000
2	20.000	24.0000

Input Structural Properties for Pile Sections:

Pile Section No. 1:

Section 1 is a round drilled shaft, bored pile, or CIDH pile
Length of section = 20.000000 ft

Shaft Diameter	=	24.000000 in

Soil and Rock Layering Information

The soil profile is modelled using 4 layers

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

Distance from top of pile to top of layer	=	0.0000 ft
Distance from top of pile to bottom of layer	=	4.000000 ft
Effective unit weight at top of layer	=	110.000000 pcf
Effective unit weight at bottom of layer	=	110.000000 pcf
Friction angle at top of layer	=	25.000000 deg.
Friction angle at bottom of layer	=	25.000000 deg.
Subgrade k at top of layer	=	25.000000 pci
Subgrade k at bottom of layer	=	25.000000 pci

Layer 2 is sand, p-y criteria by Reese et al., 1974

Distance from top of pile to top of layer	=	4.000000 ft
Distance from top of pile to bottom of layer	=	11.500000 ft
Effective unit weight at top of layer	=	67.600000 pcf
Effective unit weight at bottom of layer	=	67.600000 pcf
Friction angle at top of layer	=	25.000000 deg.
Friction angle at bottom of layer	=	25.000000 deg.
Subgrade k at top of layer	=	20.000000 pci
Subgrade k at bottom of layer	=	20.000000 pci

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

Distance from top of pile to top of layer	=	11.500000 ft
Distance from top of pile to bottom of layer	=	17.000000 ft
Effective unit weight at top of layer	=	72.600000 pcf
Effective unit weight at bottom of layer	=	72.600000 pcf
Friction angle at top of layer	=	35.000000 deg.
Friction angle at bottom of layer	=	35.000000 deg.
Subgrade k at top of layer	=	125.000000 pci
Subgrade k at bottom of layer	=	125.000000 pci

Layer 4 is weak rock, p-y criteria by Reese, 1997

Distance from top of pile to top of layer	=	17.000000 ft
Distance from top of pile to bottom of layer	=	30.000000 ft

```
   Effective unit weight at top of layer               =    77.600000 pcf
   Effective unit weight at bottom of layer            =    77.600000 pcf
   Uniaxial compressive strength at top of layer       =   200.000000 psi
   Uniaxial compressive strength at bottom of layer    =   200.000000 psi
   Initial modulus of rock at top of layer             =     1420000. psi
   Initial modulus of rock at bottom of layer          =     1420000. psi
   RQD of rock at top of layer                         =    51.000000 %
   RQD of rock at bottom of layer                      =    51.000000 %
   k rm of rock at top of layer                        =    0.0000500
   k rm of rock at bottom of layer                     =    0.0000500


 (Depth of the lowest soil layer extends 10.000 ft below the pile tip)
```

Summary of Input Soil Properties

Layer Num.	Soil Type Name or (p-y Curve Type)	Layer Depth ft	Effective Unit Wt. pcf	Angle of Friction deg.	Uniaxial qu psi	RQD %	E50 or krm	kpy	Rock Mass Modulus pci	psi
1	Sand (Reese, et al.)	0.00	110.0000	25.0000	--	--	--	25.0000	--	--
		4.0000	110.0000	25.0000	--	--	--	25.0000	--	--
2	Sand (Reese, et al.)	4.0000	67.6000	25.0000	--	--	--	20.0000	--	--
		11.5000	67.6000	25.0000	--	--	--	20.0000	--	--
3	Sand (Reese, et al.)	11.5000	72.6000	35.0000	--	--	--	125.0000	--	--
		17.0000	72.6000	35.0000	--	--	--	125.0000	--	--
4	Weak Rock	17.0000	77.6000	--	200.0000	51.0000	5.00E-05	--	1420000.	
		30.0000	77.6000	--	200.0000	51.0000	5.00E-05	--	1420000.	

Static Loading Type

Static loading criteria were used when computing p-y curves for all analyses.

Pile-head Loading and Pile-head Fixity Conditions

Number of loads specified = 1

Load No.	Load Type	Condition 1	Condition 2	Axial Thrust Force, lbs	Compute Top y vs. Pile Length	Run Analysis
1	1	V = 1551. lbs	M = 167533. in-lbs	1531.	No	Yes

V = shear force applied normal to pile axis
M = bending moment applied to pile head
y = lateral deflection normal to pile axis
S = pile slope relative to original pile batter angle
R = rotational stiffness applied to pile head
Values of top y vs. pile lengths can be computed only for load types with specified shear loading (Load Types 1, 2, and 3).
Thrust force is assumed to be acting axially for all pile batter angles.

Computations of Nominal Moment Capacity and Nonlinear Bending Stiffness

---

Axial thrust force values were determined from pile-head loading conditions

Number of Pile Sections Analyzed = 1

Pile Section No. 1:

Dimensions and Properties of Drilled Shaft (Bored Pile):

Length of Section	=	20.000000 ft
Shaft Diameter	=	24.000000 in
Concrete Cover Thickness (to edge of long. rebar)	=	4.000000 in
Number of Reinforcing Bars	=	12 bars
Yield Stress of Reinforcing Bars	=	60000. psi
Modulus of Elasticity of Reinforcing Bars	=	29000000. psi

Gross Area of Shaft	=	452.389342 sq. in.
Total Area of Reinforcing Steel	=	9.480000 sq. in.
Area Ratio of Steel Reinforcement	=	2.10 percent
Edge-to-Edge Bar Spacing	=	2.882286 in
Maximum Concrete Aggregate Size	=	0.500000 in
Ratio of Bar Spacing to Aggregate Size	=	5.76
Offset of Center of Rebar Cage from Center of Pile	=	0.0000 in

Axial Structural Capacities:

Nom. Axial Structural Capacity = 0.85 Fc Ac + Fy As	=	2074.692 kips
Tensile Load for Cracking of Concrete	=	-215.928 kips
Nominal Axial Tensile Capacity	=	-568.800 kips

Reinforcing Bar Dimensions and Positions Used in Computations:

Bar Number	Bar Diam. inches	Bar Area sq. in.	X inches	Y inches
1	1.000000	0.790000	7.500000	0.00000
2	1.000000	0.790000	6.495191	3.750000
3	1.000000	0.790000	3.750000	6.495191
4	1.000000	0.790000	0.00000	7.500000
5	1.000000	0.790000	-3.75000	6.495191
6	1.000000	0.790000	-6.49519	3.750000
7	1.000000	0.790000	-7.50000	0.00000
8	1.000000	0.790000	-6.49519	-3.75000
9	1.000000	0.790000	-3.75000	-6.49519
10	1.000000	0.790000	0.00000	-7.50000
11	1.000000	0.790000	3.750000	-6.49519
12	1.000000	0.790000	6.495191	-3.75000

NOTE: The positions of the above rebars were computed by LPile

Minimum spacing between any two bars not equal to zero = 2.882 inches
between bars 7 and 8.

Ratio of bar spacing to maximum aggregate size = 5.76

Concrete Properties:

Compressive Strength of Concrete	=	4000. psi
Modulus of Elasticity of Concrete	=	3604997. psi
Modulus of Rupture of Concrete	=	-474.34165 psi
Compression Strain at Peak Stress	=	0.001886

Tensile Strain at Fracture of Concrete = -0.0001154
Maximum Coarse Aggregate Size = 0.500000 in

Number of Axial Thrust Force Values Determined from Pile-head Loadings = 1

Number	Axial Thrust Force kips
1	1.531

Definitions of Run Messages and Notes:

C = concrete in section has cracked in tension.
Y = stress in reinforcing steel has reached yield stress.
T = ACI 318 criteria for tension-controlled section met, tensile strain in reinforcement exceeds 0.005 while simultaneously compressive strain in concrete more than 0.003. See ACI 318-14, Section 21.2.3.
Z = depth of tensile zone in concrete section is less than 10 percent of section depth.

Bending Stiffness (EI) = Computed Bending Moment / Curvature.
Position of neutral axis is measured from edge of compression side of pile.
Compressive stresses and strains are positive in sign.
Tensile stresses and strains are negative in sign.

Axial Thrust Force = 1.531 kips

Bending Max Conc Curvature rad/in.	Bending Max Steel Stress ksi	Bending Moment Stress in-kip	Run Msg	Stiffness kip-in2	Depth to N Axis in	Max Comp Strain in/in	Max Tens Strain in/in
0.00000125	94.3897384	75511791.		12.5704778	0.00001571	-0.00001429	
0.0657335	0.3121298						
0.00000250	188.3206657	75328266.		12.2861655	0.00003072	-0.00002928	
0.1279570	0.6036470						
0.00000375	281.7912546	75144335.		12.1913986	0.00004572	-0.00004428	
0.1896846	0.8951646						
0.00000500	374.8015047	74960301.		12.1440181	0.00006072	-0.00005928	
0.2509163	1.1866826						
0.00000625	467.3514161	74776227.		12.1155921	0.00007572	-0.00007428	
0.3116520	1.4782011						
0.00000750	559.4409887	74592132.		12.0966433	0.00009072	-0.00008928	

```
 0.3718918     1.7697199
0.00000875   651.0702224     74408025.    12.0831101     0.0001057     -0.000104
 0.4316357     2.0612392
0.00001000   651.0702224     65107022.     7.2959388    0.00007296     -0.000167
 0.2985549     -3.695778 C
0.00001125   651.0702224     57872909.     7.2757617    0.00008185     -0.000188
 0.3341386     -4.164333 C
0.00001250   651.0702224     52085618.     7.2601336    0.00009075     -0.000209
 0.3695763     -4.632702 C
0.00001375   651.0702224     47350562.     7.2478157    0.00009966     -0.000230
 0.4048679     -5.100883 C
0.00001500   651.0702224     43404681.     7.2379820     0.0001086     -0.000251
 0.4400130     -5.568878 C
0.00001625   651.0702224     40065860.     7.2300608     0.0001175     -0.000273
 0.4750113     -6.036684 C
0.00001750   651.0702224     37204013.     7.2236435     0.0001264     -0.000294
 0.5098625     -6.504301 C
0.00001875   651.0702224     34723745.     7.2184308     0.0001353     -0.000315
 0.5445664     -6.971728 C
0.00002000   651.0702224     32553511.     7.2141981     0.0001443     -0.000336
 0.5791226     -7.438965 C
0.00002125   651.0702224     30638599.     7.2107734     0.0001532     -0.000357
 0.6135309     -7.906011 C
0.00002250   651.0702224     28936454.     7.2080234     0.0001622     -0.000378
 0.6477909     -8.372865 C
0.00002375   651.0702224     27413483.     7.2058424     0.0001711     -0.000399
 0.6819024     -8.839526 C
0.00002500   651.0702224     26042809.     7.2041462     0.0001801     -0.000420
 0.7158651     -9.305994 C
0.00002625   651.0702224     24802675.     7.2028665     0.0001891     -0.000441
 0.7496787     -9.772268 C
0.00002750   651.0702224     23675281.     7.2019475     0.0001981     -0.000462
 0.7833429    -10.238347 C
0.00002875   651.0702224     22645921.     7.2013429     0.0002070     -0.000483
 0.8168573    -10.704230 C
0.00003000   651.0702224     21702341.     7.2010144     0.0002160     -0.000504
 0.8502217    -11.169917 C
0.00003125   651.0702224     20834247.     7.2009296     0.0002250     -0.000525
 0.8834358    -11.635407 C
0.00003250   651.1366545     20034974.     7.2010613     0.0002340     -0.000546
 0.9164992    -12.100700 C
0.00003375   675.5724529     20016962.     7.2013861     0.0002430     -0.000567
 0.9494116    -12.565793 C
0.00003500   699.9839821     19999542.     7.2018842     0.0002521     -0.000588
 0.9821728    -13.030687 C
0.00003625   724.3711599     19982653.     7.2025384     0.0002611     -0.000609
 1.0147825    -13.495381 C
0.00003750   748.7339032     19966237.     7.2033338     0.0002701     -0.000630
 1.0472402    -13.959874 C
0.00003875   773.0721286     19950248.     7.2042574     0.0002792     -0.000651
```

```
 1.0795457    -14.424166 C
0.00004000   797.3857521     19934644.     7.2052980     0.0002882     -0.000672
 1.1116987    -14.888254 C
0.00004125   821.6746892     19919386.     7.2064454     0.0002973     -0.000693
 1.1436989    -15.352140 C
0.00004250   845.9388547     19904444.     7.2076911     0.0003063     -0.000714
 1.1755459    -15.815821 C
0.00004375   870.1781629     19889787.     7.2090271     0.0003154     -0.000735
 1.2072394    -16.279297 C
0.00004500   894.3925275     19875389.     7.2104467     0.0003245     -0.000756
 1.2387791    -16.742567 C
0.00004625   918.5818616     19861229.     7.2119435     0.0003336     -0.000776
 1.2701647    -17.205631 C
0.00004750   942.7460780     19847286.     7.2135123     0.0003426     -0.000797
 1.3013958    -17.668487 C
0.00004875   966.8850884     19833540.     7.2151479     0.0003517     -0.000818
 1.3324721    -18.131135 C
0.00005125        1015.      19806578.     7.2186026     0.0003700     -0.000860
 1.3941589    -19.055802 C
0.00005375        1063.      19780229.     7.2222771     0.0003882     -0.000902
 1.4552225    -19.979625 C
0.00005625        1111.      19754397.     7.2261464     0.0004065     -0.000944
 1.5156602    -20.902598 C
0.00005875        1159.      19729004.     7.2301898     0.0004248     -0.000985
 1.5754692    -21.824714 C
0.00006125        1207.      19703985.     7.2343899     0.0004431     -0.001027
 1.6346467    -22.745965 C
0.00006375        1255.      19679283.     7.2387322     0.0004615     -0.001069
 1.6931899    -23.666344 C
0.00006625        1302.      19654851.     7.2432046     0.0004799     -0.001110
 1.7510960    -24.585843 C
0.00006875        1350.      19630648.     7.2477965     0.0004983     -0.001152
 1.8083620    -25.504456 C
0.00007125        1397.      19606639.     7.2524991     0.0005167     -0.001193
 1.8649850    -26.422174 C
0.00007375        1444.      19582793.     7.2573047     0.0005352     -0.001235
 1.9209621    -27.338989 C
0.00007625        1491.      19559084.     7.2622067     0.0005537     -0.001276
 1.9762903    -28.254895 C
0.00007875        1538.      19535489.     7.2671995     0.0005723     -0.001318
 2.0309665    -29.169883 C
0.00008125        1585.      19511985.     7.2722780     0.0005909     -0.001359
 2.0849876    -30.083945 C
0.00008375        1632.      19488556.     7.2774381     0.0006095     -0.001401
 2.1383506    -30.997072 C
0.00008625        1679.      19465184.     7.2826759     0.0006281     -0.001442
 2.1910523    -31.909257 C
0.00008875        1725.      19441855.     7.2879882     0.0006468     -0.001483
 2.2430894    -32.820490 C
0.00009125        1772.      19418556.     7.2933721     0.0006655     -0.001524
```

 2.2944588   -33.730764 C
0.00009375   1818.   19395274.   7.2988251   0.0006843   -0.001566
 2.3451571   -34.640069 C
0.00009625   1865.   19372000.   7.3043451   0.0007030   -0.001607
 2.3951810   -35.548397 C
0.00009875   1911.   19348721.   7.3099300   0.0007219   -0.001648
 2.4445272   -36.455738 C
 0.0001013   1957.   19325431.   7.3155782   0.0007407   -0.001689
 2.4931922   -37.362083 C
 0.0001038   2003.   19302127.   7.3212463   0.0007596   -0.001730
 2.5411613   -38.267550 C
 0.0001063   2048.   19278820.   7.3268283   0.0007785   -0.001772
 2.5884029   -39.172460 C
 0.0001088   2094.   19255482.   7.3324667   0.0007974   -0.001813
 2.6349513   -40.076383 C
 0.0001113   2140.   19232105.   7.3381605   0.0008164   -0.001854
 2.6808029   -40.979309 C
 0.0001138   2185.   19208684.   7.3439089   0.0008354   -0.001895
 2.7259543   -41.881230 C
 0.0001163   2230.   19185214.   7.3497113   0.0008544   -0.001936
 2.7704018   -42.782136 C
 0.0001188   2275.   19161688.   7.3555669   0.0008735   -0.001977
 2.8141418   -43.682016 C
 0.0001213   2320.   19138101.   7.3614754   0.0008926   -0.002017
 2.8571706   -44.580862 C
 0.0001238   2365.   19114450.   7.3674363   0.0009117   -0.002058
 2.8994843   -45.478663 C
 0.0001263   2410.   19090729.   7.3734492   0.0009309   -0.002099
 2.9410793   -46.375409 C
 0.0001288   2455.   19066934.   7.3795140   0.0009501   -0.002140
 2.9819515   -47.271089 C
 0.0001313   2499.   19043061.   7.3856303   0.0009694   -0.002181
 3.0220972   -48.165694 C
 0.0001338   2544.   19019106.   7.3917981   0.0009887   -0.002221
 3.0615123   -49.059213 C
 0.0001363   2588.   18995066.   7.3980173   0.0010080   -0.002262
 3.1001928   -49.951634 C
 0.0001388   2632.   18970935.   7.4042878   0.0010273   -0.002303
 3.1381345   -50.842946 C
 0.0001413   2676.   18946712.   7.4106098   0.0010467   -0.002343
 3.1753333   -51.733139 C
 0.0001438   2720.   18922393.   7.4169833   0.0010662   -0.002384
 3.2117850   -52.622201 C
 0.0001463   2764.   18897973.   7.4234083   0.0010857   -0.002424
 3.2474853   -53.510119 C
 0.0001488   2807.   18873451.   7.4298852   0.0011052   -0.002465
 3.2824298   -54.396882 C
 0.0001588   2980.   18774268.   7.4563149   0.0011837   -0.002626
 3.4145604   -57.932140 C
 0.0001688   3150.   18666275.   7.4826813   0.0012627   -0.002787

```
3.5340078    -60.000000 CY
0.0001788         3299.     18455239.     7.4959244     0.0013399     -0.002950
3.6375234    -60.000000 CY
0.0001888         3421.     18123687.     7.4917650     0.0014141     -0.003116
3.7247043    -60.000000 CY
0.0001988         3505.     17632920.     7.4619846     0.0014831     -0.003287
3.7949724    -60.000000 CY
0.0002088         3578.     17140737.     7.4305173     0.0015511     -0.003459
3.8541387    -60.000000 CY
0.0002188         3650.     16687980.     7.4041948     0.0016197     -0.003630
3.9035834    -60.000000 CY
0.0002288         3722.     16269301.     7.3824249     0.0016887     -0.003801
3.9430908    -60.000000 CY
0.0002388         3789.     15871921.     7.3629620     0.0017579     -0.003972
3.9722842    -60.000000 CY
0.0002488         3843.     15448339.     7.3355841     0.0018247     -0.004145
3.9906095    -60.000000 CY
0.0002588         3879.     14989826.     7.2965791     0.0018880     -0.004322
3.9990328    -60.000000 CY
0.0002688         3907.     14537764.     7.2554624     0.0019499     -0.004500
3.9987671    -60.000000 CY
0.0002788         3934.     14113829.     7.2186927     0.0020122     -0.004678
3.9980815    -60.000000 CY
0.0002888         3961.     13716273.     7.1861389     0.0020750     -0.004855
3.9967432    -60.000000 CY
0.0002988         3986.     13342560.     7.1573548     0.0021383     -0.005032
3.9996743    -60.000000 CY
0.0003088         4011.     12990294.     7.1320369     0.0022020     -0.005208
3.9996476    -60.000000 CY
0.0003188         4035.     12657736.     7.1097627     0.0022662     -0.005384
3.9981300    -60.000000 CY
0.0003288         4058.     12343283.     7.0901830     0.0023309     -0.005559
3.9966526    -60.000000 CY
0.0003388         4080.     12045182.     7.0726937     0.0023959     -0.005734
3.9996007    -60.000000 CY
0.0003488         4102.     11762194.     7.0569374     0.0024611     -0.005909
3.9968523    -60.000000 CY
0.0003588         4123.     11493437.     7.0432005     0.0025267     -0.006083
3.9999687    -60.000000 CY
0.0003688         4144.     11237503.     7.0314844     0.0025929     -0.006257
3.9976561    -60.000000 CY
0.0003788         4164.     10993715.     7.0212518     0.0026593     -0.006431
3.9998814    -60.000000 CY
0.0003888         4183.     10759463.     7.0120245     0.0027259     -0.006604
3.9975486    -60.000000 CY
0.0003988         4199.     10529741.     7.0008071     0.0027916     -0.006778
3.9999833    -60.000000 CY
0.0004088         4212.     10304889.     6.9883180     0.0028565     -0.006954
3.9959736    -60.000000 CY
0.0004188         4223.     10085084.     6.9742679     0.0029205     -0.007130
```

```
    3.9995020    -60.000000 CY
    0.0004288         4231.      9867756.     6.9574073     0.0029830     -0.007307
    3.9948997    -60.000000 CY
    0.0004388         4237.      9657233.     6.9404446     0.0030451     -0.007485
    3.9969483    -60.000000 CYT
    0.0004488         4241.      9450373.     6.9212621     0.0031059     -0.007664
    3.9995982    -60.000000 CYT
    0.0004588         4244.      9251355.     6.9029363     0.0031667     -0.007843
    3.9955163    -60.000000 CYT
    0.0004688         4247.      9060334.     6.8858207     0.0032277     -0.008022
    3.9952804    -60.000000 CYT
    0.0004788         4250.      8877067.     6.8697396     0.0032889     -0.008201
    3.9987283    -60.000000 CYT
    0.0004888         4253.      8701087.     6.8546455     0.0033502     -0.008380
    3.9999940    -60.000000 CYT
    0.0004988         4255.      8531753.     6.8407169     0.0034118     -0.008558
    3.9908179    -60.000000 CYT
    0.0005088         4258.      8368701.     6.8265212     0.0034730     -0.008737
    3.9957302    -60.000000 CYT
    0.0005188         4260.      8211774.     6.8130874     0.0035343     -0.008916
    3.9987955    -60.000000 CYT
    0.0005288         4262.      8060633.     6.8004376     0.0035957     -0.009094
    3.9999847    -60.000000 CYT
    0.0005388         4264.      7914796.     6.7887542     0.0036574     -0.009273
    3.9919674    -60.000000 CYT
    0.0005488         4266.      7774138.     6.7777555     0.0037193     -0.009451
    3.9933988    -60.000000 CYT
    0.0006088         4266.      7007898.     6.7766348     0.0041253     -0.010485
    3.9992664    -60.000000 CYT


--------------------------------------------------------------------------------
   Summary of Results for Nominal Moment Capacity for Section 1
--------------------------------------------------------------------------------

Moment values interpolated at maximum compressive strain = 0.003
or maximum developed moment if pile fails at smaller strains.

 Load           Axial Thrust        Nominal Mom. Cap.      Max. Comp.      Max.
Tens.
  No.              kips                 in-kip               Strain
Strain
 ----         ----------------     ------------------     ------------
------------
   1                1.531              4232.528           0.00300000
-0.00735571

Note that the values of moment capacity in the table above are not
factored by a strength reduction factor (phi-factor).
```

In ACI 318, the value of the strength reduction factor depends on whether the transverse reinforcing steel bars are tied hoops (0.65) or spirals (0.75).

The above values should be multiplied by the appropriate strength reduction factor to compute ultimate moment capacity according to ACI 318, or the value required by the design standard being followed.

The following table presents factored moment capacities and corresponding bending stiffnesses computed for common resistance factor values used for reinforced concrete sections.

Axial Load No.	Resist. Factor	Nominal Ax. Thrust kips	Nominal Moment Cap in-kips	Ult. (Fac) Ax. Thrust kips	Ult. (Fac) Moment Cap in-kips	Bend. Stiff. at Ult Mom kip-in^2
1	0.65	1.530600	4233.	0.994890	2751.	18905056.
1	0.75	1.530600	4233.	1.147950	3174.	18631614.
1	0.90	1.530600	4233.	1.377540	3809.	15714293.

Layering Correction Equivalent Depths of Soil & Rock Layers

Layer No.	Top of Layer Below Pile Head ft	Equivalent Top Depth Below Grnd Surf ft	Same Layer Type As Layer Above	Layer is Rock or is Below Rock Layer	F0 Integral for Layer lbs	F1 Integral for Layer lbs
1	0.00	0.00	N.A.	No	0.00	11790.
2	4.0000	4.0000	Yes	No	11790.	69203.
3	11.5000	8.6139	Yes	No	80993.	182150.
4	17.0000	17.0000	No	Yes	N.A.	N.A.

Notes: The F0 integral of Layer n+1 equals the sum of the F0 and F1 integrals for Layer n. Layering correction equivalent depths are computed only for soil types with both shallow-depth and deep-depth expressions for peak lateral load transfer. These soil types are soft and stiff clays, non-liquefied sands, and cemented c-phi soil.

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

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

Shear force at pile head = 1551.2 lbs
Applied moment at pile head = 167532.7 in-lbs
Axial thrust load on pile head = 1530.6 lbs

Depth X	Deflect. y	Bending Moment	Shear Force	Slope S	Total Stress	Bending Stiffness	Soil Res. Es*H	Soil Spr. Lat. Load	Distrib. p
feet	inches	in-lbs	lbs	radians	psi*	lb-in^2	lb/inch	lb/inch	lb/inch
0.00	0.04701	167533.	1551.	-5.10E-04	0.00	7.54E+10	0.00	0.00	0.00
0.2000	0.04579	171258.	1548.	-5.05E-04	0.00	7.54E+10	-2.748	144.0000	0.00
0.4000	0.04459	174967.	1538.	-4.99E-04	0.00	7.53E+10	-5.350	288.0000	0.00
0.6000	0.04340	178645.	1522.	-4.94E-04	0.00	7.53E+10	-7.811	432.0000	0.00
0.8000	0.04222	182278.	1501.	-4.88E-04	0.00	7.53E+10	-10.132	576.0000	0.00
1.0000	0.04105	185852.	1474.	-4.82E-04	0.00	7.53E+10	-12.316	720.0000	0.00
1.2000	0.03990	189356.	1442.	-4.76E-04	0.00	7.53E+10	-14.365	864.0000	0.00
1.4000	0.03877	192777.	1405.	-4.70E-04	0.00	7.53E+10	-16.282	1008.	0.00
1.6000	0.03765	196104.	1364.	-4.64E-04	0.00	7.53E+10	-18.071	1152.	0.00
1.8000	0.03654	199328.	1319.	-4.58E-04	0.00	7.53E+10	-19.732	1296.	0.00
2.0000	0.03545	202437.	1269.	-4.51E-04	0.00	7.53E+10	-21.271	1440.	0.00
2.2000	0.03438	205424.	1217.	-4.45E-04	0.00	7.53E+10	-22.688	1584.	0.00
2.4000	0.03332	208280.	1161.	-4.38E-04	0.00	7.53E+10	-23.988	1728.	0.00
2.6000	0.03227	210998.	1102.	-4.31E-04	0.00	7.53E+10			

```
-25.174      1872.       0.00
    2.8000    0.03125    213571.      1040.  -4.25E-04       0.00   7.53E+10
-26.247      2016.       0.00
    3.0000    0.03024    215993.   975.7529  -4.18E-04       0.00   7.53E+10
-27.212      2160.       0.00
    3.2000    0.02924    218258.   909.4117  -4.11E-04       0.00   7.53E+10
-28.072      2304.       0.00
    3.4000    0.02826    220361.   841.1298  -4.04E-04       0.00   7.52E+10
-28.829      2448.       0.00
    3.6000    0.02730    222298.   771.1490  -3.97E-04       0.00   7.52E+10
-29.488      2592.       0.00
    3.8000    0.02636    224065.   699.7033  -3.90E-04       0.00   7.52E+10
-30.050      2736.       0.00
    4.0000    0.02543    225659.   634.3436  -3.82E-04       0.00   7.52E+10
-24.416      2304.       0.00
    4.2000    0.02452    227113.   575.3798  -3.75E-04       0.00   7.52E+10
-24.720      2419.       0.00
    4.4000    0.02363    228424.   515.7683  -3.68E-04       0.00   7.52E+10
-24.956      2534.       0.00
    4.6000    0.02276    229591.   455.6714  -3.61E-04       0.00   7.52E+10
-25.125      2650.       0.00
    4.8000    0.02190    230614.   395.2451  -3.53E-04       0.00   7.52E+10
-25.230      2765.       0.00
    5.0000    0.02106    231491.   334.6391  -3.46E-04       0.00   7.52E+10
-25.275      2880.       0.00
    5.2000    0.02024    232223.   273.9968  -3.39E-04       0.00   7.52E+10
-25.261      2995.       0.00
    5.4000    0.01944    232809.   213.4552  -3.31E-04       0.00   7.52E+10
-25.191      3110.       0.00
    5.6000    0.01865    233250.   153.1451  -3.24E-04       0.00   7.52E+10
-25.068      3226.       0.00
    5.8000    0.01788    233546.    93.1911  -3.16E-04       0.00   7.52E+10
-24.894      3341.       0.00
    6.0000    0.01713    233699.    33.7114  -3.09E-04       0.00   7.52E+10
-24.672      3456.       0.00
    6.2000    0.01640    233710.    -25.182  -3.01E-04       0.00   7.52E+10
-24.405      3571.       0.00
    6.4000    0.01569    233581.    -83.383  -2.94E-04       0.00   7.52E+10
-24.096      3686.       0.00
    6.6000    0.01499    233312.   -140.793  -2.86E-04       0.00   7.52E+10
-23.746      3802.       0.00
    6.8000    0.01431    232907.   -197.317  -2.79E-04       0.00   7.52E+10
-23.358      3917.       0.00
    7.0000    0.01365    232367.   -252.869  -2.72E-04       0.00   7.52E+10
-22.935      4032.       0.00
    7.2000    0.01301    231695.   -307.366  -2.64E-04       0.00   7.52E+10
-22.480      4147.       0.00
    7.4000    0.01238    230894.   -360.734  -2.57E-04       0.00   7.52E+10
-21.994      4262.       0.00
    7.6000    0.01178    229966.   -412.903  -2.49E-04       0.00   7.52E+10
```

```
-21.480      4378.       0.00
    7.8000    0.01119    228914.   -463.809  -2.42E-04       0.00   7.52E+10
-20.941      4493.       0.00
    8.0000    0.01061    227741.   -513.395  -2.35E-04       0.00   7.52E+10
-20.380      4608.       0.00
    8.2000    0.01006    226451.   -561.607  -2.28E-04       0.00   7.52E+10
-19.797      4723.       0.00
    8.4000    0.00952    225047.   -608.399  -2.20E-04       0.00   7.52E+10
-19.196      4838.       0.00
    8.6000    0.00900    223532.   -653.730  -2.13E-04       0.00   7.52E+10
-18.580      4954.       0.00
    8.8000    0.00850    221911.   -697.564  -2.06E-04       0.00   7.52E+10
-17.949      5069.       0.00
    9.0000    0.00801    220186.   -739.871  -1.99E-04       0.00   7.52E+10
-17.307      5184.       0.00
    9.2000    0.00754    218361.   -780.625  -1.92E-04       0.00   7.53E+10
-16.655      5299.       0.00
    9.4000    0.00709    216440.   -819.806  -1.85E-04       0.00   7.53E+10
-15.996      5414.       0.00
    9.6000    0.00665    214427.   -857.400  -1.78E-04       0.00   7.53E+10
-15.332      5530.       0.00
    9.8000    0.00623    212326.   -893.394  -1.71E-04       0.00   7.53E+10
-14.664      5645.       0.00
   10.0000    0.00583    210140.   -927.786  -1.65E-04       0.00   7.53E+10
-13.995      5760.       0.00
   10.2000    0.00544    207874.   -960.572  -1.58E-04       0.00   7.53E+10
-13.327      5875.       0.00
   10.4000    0.00507    205530.   -991.758  -1.51E-04       0.00   7.53E+10
-12.661      5990.       0.00
   10.6000    0.00472    203114.     -1021.  -1.45E-04       0.00   7.53E+10
-12.000      6106.       0.00
   10.8000    0.00438    200629.     -1049.  -1.39E-04       0.00   7.53E+10
-11.345      6221.       0.00
   11.0000    0.00405    198078.     -1076.  -1.32E-04       0.00   7.53E+10
-10.697      6336.       0.00
   11.2000    0.00374    195466.     -1101.  -1.26E-04       0.00   7.53E+10
-10.060      6451.       0.00
   11.4000    0.00345    192796.     -1124.  -1.20E-04       0.00   7.53E+10
-9.433       6566.       0.00
   11.6000    0.00317    190071.     -1202.  -1.14E-04       0.00   7.53E+10
-55.119     41760.       0.00
   11.8000    0.00290    187029.     -1329.  -1.08E-04       0.00   7.53E+10
-51.372     42480.       0.00
   12.0000    0.00265    183691.     -1448.  -1.02E-04       0.00   7.53E+10
-47.722     43200.       0.00
   12.2000    0.00241    180078.     -1559.  -9.59E-05       0.00   7.53E+10
-44.180     43920.       0.00
   12.4000    0.00219    176211.     -1660.  -9.02E-05       0.00   7.53E+10
-40.751     44640.       0.00
   12.6000    0.00198    172108.     -1754.  -8.47E-05       0.00   7.53E+10
```

```
-37.442     45360.       0.00
   12.8000    0.00178    167791.     -1840.  -7.93E-05       0.00   7.54E+10
-34.261     46080.       0.00
   13.0000    0.00160    163275.     -1919.  -7.40E-05       0.00   7.54E+10
-31.211     46800.       0.00
   13.2000    0.00143    158580.     -1990.  -6.89E-05       0.00   7.54E+10
-28.298     47520.       0.00
   13.4000    0.00127    153722.     -2055.  -6.39E-05       0.00   7.54E+10
-25.526     48240.       0.00
   13.6000    0.00112    148717.     -2113.  -5.91E-05       0.00   7.54E+10
-22.899     48960.       0.00
   13.8000   9.86E-04    143580.     -2165.  -5.44E-05       0.00   7.54E+10
-20.418     49680.       0.00
   14.0000   8.61E-04    138325.     -2211.  -4.99E-05       0.00   7.54E+10
-18.085     50400.       0.00
   14.2000   7.47E-04    132967.     -2252.  -4.56E-05       0.00   7.54E+10
-15.903     51120.       0.00
   14.4000   6.42E-04    127516.     -2288.  -4.15E-05       0.00   7.54E+10
-13.871     51840.       0.00
   14.6000   5.47E-04    121986.     -2319.  -3.75E-05       0.00   7.54E+10
-11.990     52560.       0.00
   14.8000   4.62E-04    116386.     -2345.  -3.37E-05       0.00   7.54E+10
-10.259     53280.       0.00
   15.0000   3.86E-04    110728.     -2368.  -3.01E-05       0.00   7.55E+10
-8.677     54000.       0.00
   15.2000   3.18E-04    105019.     -2387.  -2.67E-05       0.00   7.55E+10
-7.241     54720.       0.00
   15.4000   2.58E-04     99269.     -2403.  -2.34E-05       0.00   7.55E+10
-5.950     55440.       0.00
   15.6000   2.05E-04     93485.     -2416.  -2.04E-05       0.00   7.55E+10
-4.800     56160.       0.00
   15.8000   1.60E-04     87672.     -2426.  -1.75E-05       0.00   7.55E+10
-3.787     56880.       0.00
   16.0000   1.21E-04     81838.     -2434.  -1.48E-05       0.00   7.55E+10
-2.908     57600.       0.00
   16.2000   8.88E-05     75988.     -2440.  -1.23E-05       0.00   7.55E+10
-2.158     58320.       0.00
   16.4000   6.22E-05     70124.     -2445.  -9.97E-06       0.00   7.55E+10
-1.530     59040.       0.00
   16.6000   4.10E-05     64252.     -2448.  -7.83E-06       0.00   7.55E+10
-1.020     59760.       0.00
   16.8000   2.46E-05     58375.     -2450.  -5.88E-06       0.00   7.55E+10
-0.620     60480.       0.00
   17.0000   1.27E-05     52493.     -3063.  -4.12E-06       0.00   7.55E+10
-510.447   9.63E+07       0.00
   17.2000   4.84E-06     43671.     -4226.  -2.59E-06       0.00   7.55E+10
-458.812   2.27E+08       0.00
   17.4000   2.90E-07     32207.     -4839.  -1.39E-06       0.00   7.55E+10
-52.190   4.32E+08       0.00
   17.6000  -1.81E-06     20442.     -4471.  -5.48E-07       0.00   7.55E+10
```

```
358.9453   4.77E+08       0.00
   17.8000  -2.34E-06     10744.     -3429.  -5.28E-08       0.00   7.55E+10
509.9271   5.23E+08       0.00
   18.0000  -2.06E-06      3984.     -2232.   1.81E-07       0.00   7.55E+10
487.2551   5.68E+08       0.00
   18.2000  -1.47E-06    30.2801     -1196.   2.45E-07       0.00   7.55E+10
376.1841   6.13E+08       0.00
   18.4000  -8.82E-07     -1757.   -453.856   2.18E-07       0.00   7.55E+10
242.2492   6.59E+08       0.00
   18.6000  -4.27E-07     -2148.    -12.773   1.56E-07       0.00   7.55E+10
125.3205   7.04E+08       0.00
   18.8000  -1.36E-07     -1818.   188.4201   9.26E-08       0.00   7.55E+10
42.3402   7.50E+08       0.00
   19.0000   1.73E-08     -1244.   232.3509   4.39E-08       0.00   7.55E+10
-5.731   7.95E+08       0.00
   19.2000   7.52E-08   -702.680   193.8449   1.30E-08       0.00   7.55E+10
-26.357   8.41E+08       0.00
   19.4000   7.96E-08   -313.361   126.9500  -3.17E-09       0.00   7.55E+10
-29.389   8.86E+08       0.00
   19.6000   6.00E-08    -93.320    63.7153  -9.63E-09       0.00   7.55E+10
-23.307   9.32E+08       0.00
   19.8000   3.34E-08     -7.527    19.4416  -1.12E-08       0.00   7.55E+10
-13.588   9.77E+08       0.00
   20.0000   6.14E-09       0.00       0.00  -1.14E-08       0.00   7.55E+10
-2.614   5.11E+08       0.00
```

* This analysis computed pile response using nonlinear moment-curvature relationships. Values of total stress due to combined axial and bending stresses are computed only for elastic sections only and do not equal the actual stresses in concrete and steel. Stresses in concrete and steel may be interpolated from the output for nonlinear bending properties relative to the magnitude of bending moment developed in the pile.

Output Summary for Load Case No. 1:

Pile-head deflection	=	0.04701001 inches
Computed slope at pile head	=	-0.0005102 radians
Maximum bending moment	=	233710. inch-lbs
Maximum shear force	=	-4839. lbs
Depth of maximum bending moment	=	6.20000000 feet below pile head
Depth of maximum shear force	=	17.40000000 feet below pile head
Number of iterations	=	6
Number of zero deflection points	=	3

Summary of Pile-head Responses for Conventional Analyses

Definitions of Pile-head Loading Conditions:

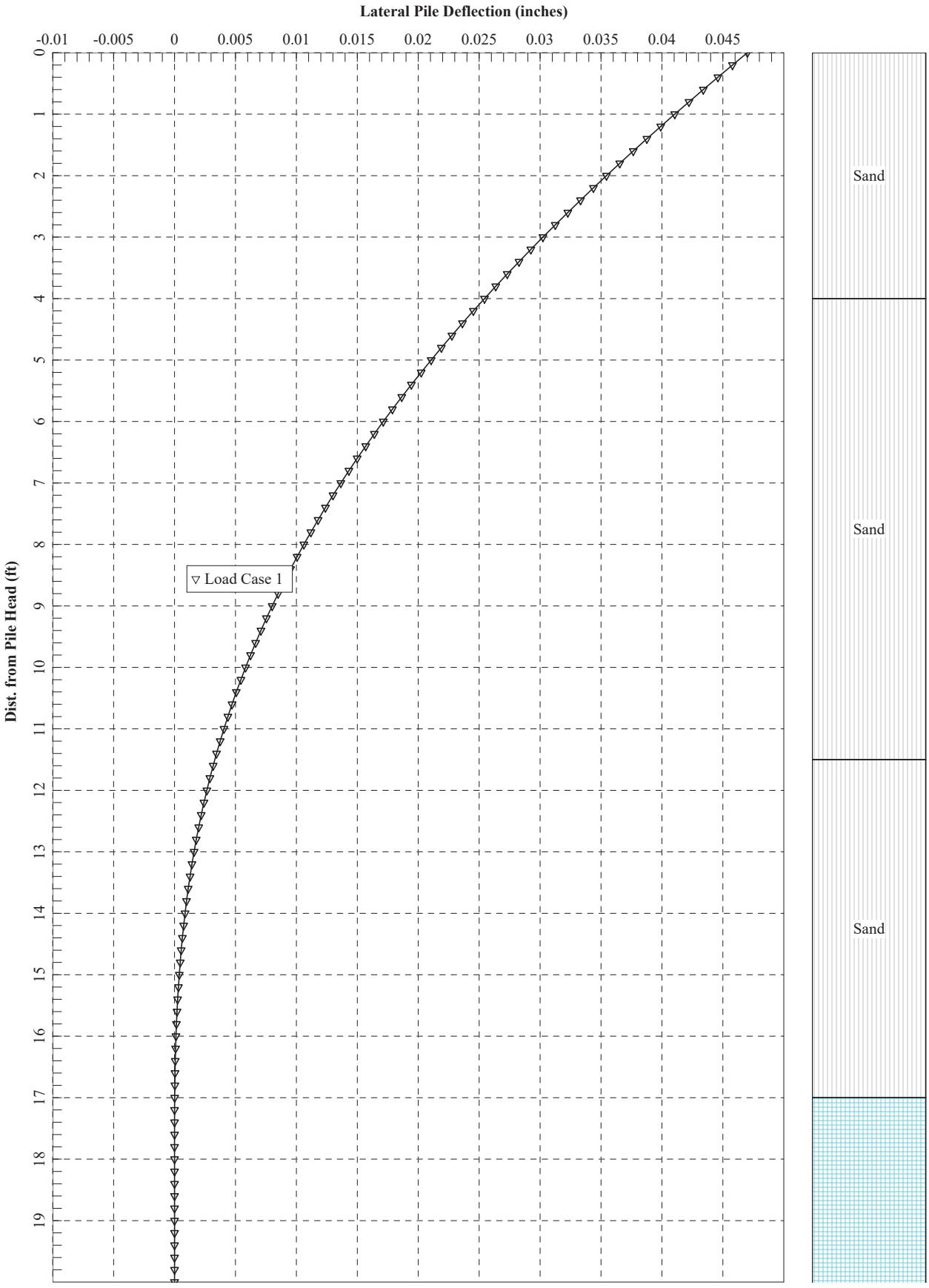
Load Type 1: Load 1 = Shear, V, lbs, and Load 2 = Moment, M, in-lbs
Load Type 2: Load 1 = Shear, V, lbs, and Load 2 = Slope, S, radians
Load Type 3: Load 1 = Shear, V, lbs, and Load 2 = Rot. Stiffness, R, in-lbs/rad.
Load Type 4: Load 1 = Top Deflection, y, inches, and Load 2 = Moment, M, in-lbs
Load Type 5: Load 1 = Top Deflection, y, inches, and Load 2 = Slope, S, radians

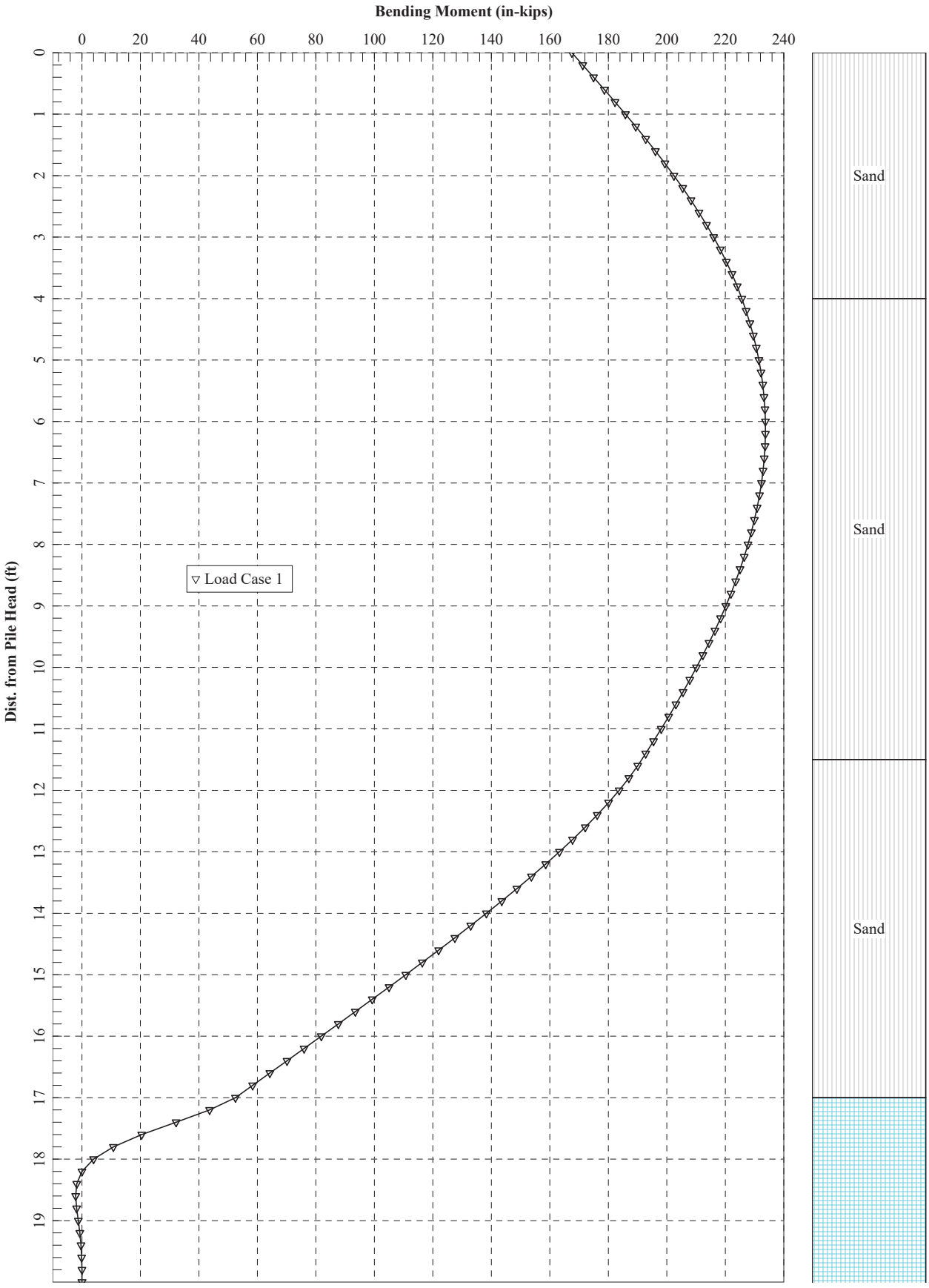
Load Case No.	Load Type	Pile-head Load 1	Load Type	Pile-head Load 2	Axial Loading lbs	Pile-head Deflection inches	Pile-head Rotation radians	Max Shear in Pile lbs	Max Moment in Pile in-lbs
1	V, lb	1551.	M, in-lb	167533.	1531.	0.04701	-5.10E-04	-4839.	233710.

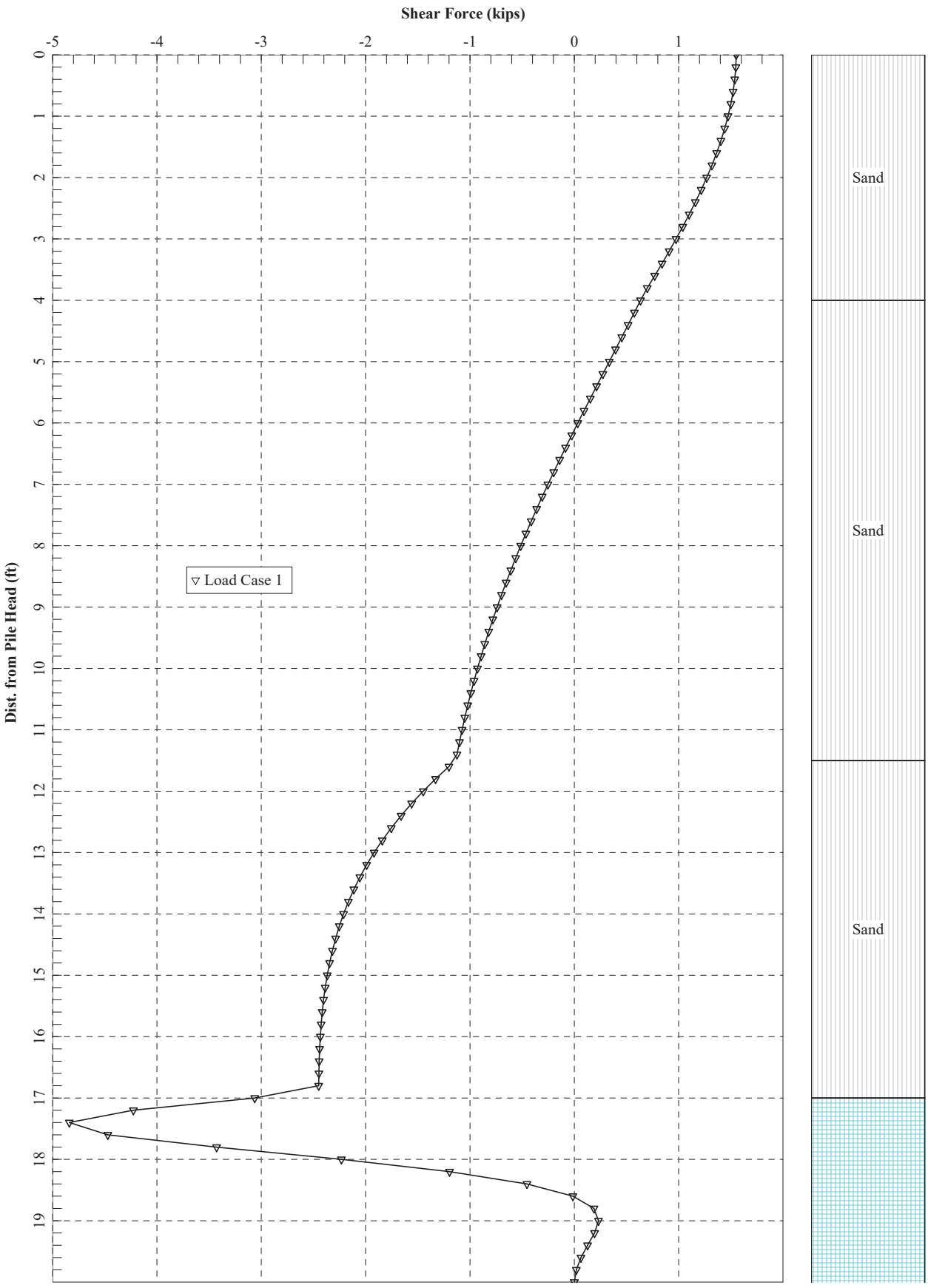
Maximum pile-head deflection = 0.0470100089 inches
Maximum pile-head rotation = -0.0005102250 radians = -0.029234 deg.

The analysis ended normally.

SER-I Load Case Anticipated Deflection (Caisson Bearing in Claystone) = 0.05 inches


Lateral Pile Deflection (inches)
-0.01
-0.005
0
0.005
0.01
0.015
0.02
0.025
0.03
0.035
0.04
0.045
Dist. from Pile Head (ft)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
Load Case 1
Sand
Sand
Sand


Bending Moment (in-kips)
0
20
40
60
80
100
120
140
160
180
200
220
240
Dist. from Pile Head (ft)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
Load Case 1
Sand
Sand
Sand


Shear Force (kips)
-5
-4
-3
-2
-1
0
1
Dist. from Pile Head (ft)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
Load Case 1
Sand
Sand
Sand

STR-I Load Case Results
Caisson Bearing in Claystone Bedrock

==========

LPile for Windows, Version 2022-12.009

Analysis of Individual Piles and Drilled Shafts
Subjected to Lateral Loading Using the p-y Method
© 1985-2022 by Ensoft, Inc.
All Rights Reserved

==========

By: SMC 07/23
Checked by: RHY 08/23

This copy of LPile is being used by:

Gannett Fleming, Inc
Pittsburgh, PA

Serial Number of Security Device: 546957815

This copy of LPile is licensed for exclusive use by:

Gannett Fleming, Inc., LPILE Sm Global, SmGlobal Licens

Use of this software by employees of Gannett Fleming, Inc.
other than those of the office site in LPILE Sm Global, SmGlobal Licens
is a violation of the software license agreement.

Files Used for Analysis

Path to file locations:
\Users\schechak\Desktop\SR88 Grade Crossing\

Name of input data file:
SR88 Grade Crossing Caisson (STR-I Load Case).lp12d

Name of output report file:
SR88 Grade Crossing Caisson (STR-I Load Case).lp12o

Name of plot output file:
SR88 Grade Crossing Caisson (STR-I Load Case).lp12p

Name of runtime message file:
SR88 Grade Crossing Caisson (STR-I Load Case).lp12r

Date and Time of Analysis

Date: July 28, 2023 Time: 12:06:02

Problem Title

Project Name: SR88 Grade Crossing Gate Foundation

Job Number: 073937.06

Client: Port Authority of Allegheny County

Engineer: S. Chechak

Description:

Program Options and Settings

Computational Options:
- Conventional Analysis

Engineering Units Used for Data Input and Computations:
- US Customary System Units (pounds, feet, inches)

Analysis Control Options:

- Maximum number of iterations allowed	=	500
- Deflection tolerance for convergence	=	1.0000E-05 in
- Maximum allowable deflection	=	100.0000 in
- Number of pile increments	=	100

Loading Type and Number of Cycles of Loading:
- Static loading specified

- Use of p-y modification factors for p-y curves not selected
- Analysis uses layering correction (Method of Georgiadis)
- No distributed lateral loads are entered
- Loading by lateral soil movements acting on pile not selected
- Input of shear resistance at the pile tip not selected
- Input of moment resistance at the pile tip not selected
- Computation of pile-head foundation stiffness matrix not selected
- Push-over analysis of pile not selected
- Buckling analysis of pile not selected

Output Options:
- Output files use decimal points to denote decimal symbols.
- Values of pile-head deflection, bending moment, shear force, and soil reaction are printed for full length of pile.
- Printing Increment (nodal spacing of output points) = 1
- No p-y curves to be computed and reported for user-specified depths
- Print using wide report formats

Pile Structural Properties and Geometry

Number of pile sections defined = 1
Total length of pile = 20.000 ft
Depth of ground surface below top of pile = 0.0000 ft

Pile diameters used for p-y curve computations are defined using 2 points.

p-y curves are computed using pile diameter values interpolated with depth over the length of the pile. A summary of values of pile diameter vs. depth follows.

Point No.	Depth Below Pile Head feet	Pile Diameter inches
1	0.000	24.0000
2	20.000	24.0000

Input Structural Properties for Pile Sections:

Pile Section No. 1:

Section 1 is a round drilled shaft, bored pile, or CIDH pile
Length of section = 20.000000 ft

Shaft Diameter	=	24.000000 in

Soil and Rock Layering Information

The soil profile is modelled using 4 layers

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

Distance from top of pile to top of layer	=	0.0000 ft
Distance from top of pile to bottom of layer	=	4.000000 ft
Effective unit weight at top of layer	=	110.000000 pcf
Effective unit weight at bottom of layer	=	110.000000 pcf
Friction angle at top of layer	=	25.000000 deg.
Friction angle at bottom of layer	=	25.000000 deg.
Subgrade k at top of layer	=	25.000000 pci
Subgrade k at bottom of layer	=	25.000000 pci

Layer 2 is sand, p-y criteria by Reese et al., 1974

Distance from top of pile to top of layer	=	4.000000 ft
Distance from top of pile to bottom of layer	=	11.500000 ft
Effective unit weight at top of layer	=	67.600000 pcf
Effective unit weight at bottom of layer	=	67.600000 pcf
Friction angle at top of layer	=	25.000000 deg.
Friction angle at bottom of layer	=	25.000000 deg.
Subgrade k at top of layer	=	20.000000 pci
Subgrade k at bottom of layer	=	20.000000 pci

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

Distance from top of pile to top of layer	=	11.500000 ft
Distance from top of pile to bottom of layer	=	17.000000 ft
Effective unit weight at top of layer	=	72.600000 pcf
Effective unit weight at bottom of layer	=	72.600000 pcf
Friction angle at top of layer	=	35.000000 deg.
Friction angle at bottom of layer	=	35.000000 deg.
Subgrade k at top of layer	=	125.000000 pci
Subgrade k at bottom of layer	=	125.000000 pci

Layer 4 is weak rock, p-y criteria by Reese, 1997

Distance from top of pile to top of layer	=	17.000000 ft
Distance from top of pile to bottom of layer	=	30.000000 ft

```
   Effective unit weight at top of layer               =    77.600000 pcf
   Effective unit weight at bottom of layer            =    77.600000 pcf
   Uniaxial compressive strength at top of layer       =   200.000000 psi
   Uniaxial compressive strength at bottom of layer    =   200.000000 psi
   Initial modulus of rock at top of layer             =     1420000. psi
   Initial modulus of rock at bottom of layer          =     1420000. psi
   RQD of rock at top of layer                         =    51.000000 %
   RQD of rock at bottom of layer                      =    51.000000 %
   k rm of rock at top of layer                        =    0.0000500
   k rm of rock at bottom of layer                     =    0.0000500


 (Depth of the lowest soil layer extends 10.000 ft below the pile tip)
```

Summary of Input Soil Properties

Layer Num.	Soil Type Name or (p-y Curve Type)	Layer Depth ft	Effective Unit Wt. pcf	Angle of Friction deg.	Uniaxial qu psi	RQD %	E50 or krm	kpy	Rock Mass Modulus pci	psi
1	Sand (Reese, et al.)	0.00	110.0000	25.0000	--	--	--	25.0000	--	--
		4.0000	110.0000	25.0000	--	--	--	25.0000	--	--
2	Sand (Reese, et al.)	4.0000	67.6000	25.0000	--	--	--	20.0000	--	--
		11.5000	67.6000	25.0000	--	--	--	20.0000	--	--
3	Sand (Reese, et al.)	11.5000	72.6000	35.0000	--	--	--	125.0000	--	--
		17.0000	72.6000	35.0000	--	--	--	125.0000	--	--
4	Weak Rock	17.0000	77.6000	--	200.0000	51.0000	5.00E-05	--	1420000.	
		30.0000	77.6000	--	200.0000	51.0000	5.00E-05	--	1420000.	

Static Loading Type

Static loading criteria were used when computing p-y curves for all analyses.

Pile-head Loading and Pile-head Fixity Conditions

Number of loads specified = 1

Load No.	Load Type	Condition 1	Condition 2	Axial Thrust Force, lbs	Compute Top y vs. Pile Length	Run Analysis
1	1	V = 1913. lbs	M = 0.0000 in-lbs	0.0000000	No	Yes

V = shear force applied normal to pile axis
M = bending moment applied to pile head
y = lateral deflection normal to pile axis
S = pile slope relative to original pile batter angle
R = rotational stiffness applied to pile head
Values of top y vs. pile lengths can be computed only for load types with specified shear loading (Load Types 1, 2, and 3).
Thrust force is assumed to be acting axially for all pile batter angles.

Computations of Nominal Moment Capacity and Nonlinear Bending Stiffness

---

Axial thrust force values were determined from pile-head loading conditions

Number of Pile Sections Analyzed = 1

Pile Section No. 1:

Dimensions and Properties of Drilled Shaft (Bored Pile):

Length of Section	=	20.000000 ft
Shaft Diameter	=	24.000000 in
Concrete Cover Thickness (to edge of long. rebar)	=	4.000000 in
Number of Reinforcing Bars	=	12 bars
Yield Stress of Reinforcing Bars	=	60000. psi
Modulus of Elasticity of Reinforcing Bars	=	29000000. psi

Gross Area of Shaft	=	452.389342 sq. in.
Total Area of Reinforcing Steel	=	9.480000 sq. in.
Area Ratio of Steel Reinforcement	=	2.10 percent
Edge-to-Edge Bar Spacing	=	2.882286 in
Maximum Concrete Aggregate Size	=	0.500000 in
Ratio of Bar Spacing to Aggregate Size	=	5.76
Offset of Center of Rebar Cage from Center of Pile	=	0.0000 in

Axial Structural Capacities:

Nom. Axial Structural Capacity = 0.85 Fc Ac + Fy As	=	2074.692 kips
Tensile Load for Cracking of Concrete	=	-215.928 kips
Nominal Axial Tensile Capacity	=	-568.800 kips

Reinforcing Bar Dimensions and Positions Used in Computations:

Bar Number	Bar Diam. inches	Bar Area sq. in.	X inches	Y inches
1	1.000000	0.790000	7.500000	0.00000
2	1.000000	0.790000	6.495191	3.750000
3	1.000000	0.790000	3.750000	6.495191
4	1.000000	0.790000	0.00000	7.500000
5	1.000000	0.790000	-3.75000	6.495191
6	1.000000	0.790000	-6.49519	3.750000
7	1.000000	0.790000	-7.50000	0.00000
8	1.000000	0.790000	-6.49519	-3.75000
9	1.000000	0.790000	-3.75000	-6.49519
10	1.000000	0.790000	0.00000	-7.50000
11	1.000000	0.790000	3.750000	-6.49519
12	1.000000	0.790000	6.495191	-3.75000

NOTE: The positions of the above rebars were computed by LPile

Minimum spacing between any two bars not equal to zero = 2.882 inches
between bars 7 and 8.

Ratio of bar spacing to maximum aggregate size = 5.76

Concrete Properties:

Compressive Strength of Concrete	=	4000. psi
Modulus of Elasticity of Concrete	=	3604997. psi
Modulus of Rupture of Concrete	=	-474.34165 psi
Compression Strain at Peak Stress	=	0.001886

Tensile Strain at Fracture of Concrete = -0.0001154
Maximum Coarse Aggregate Size = 0.500000 in

Number of Axial Thrust Force Values Determined from Pile-head Loadings = 1

Number	Axial Thrust Force kips
1	0.000

Definitions of Run Messages and Notes:

C = concrete in section has cracked in tension.
Y = stress in reinforcing steel has reached yield stress.
T = ACI 318 criteria for tension-controlled section met, tensile strain in reinforcement exceeds 0.005 while simultaneously compressive strain in concrete more than 0.003. See ACI 318-14, Section 21.2.3.
Z = depth of tensile zone in concrete section is less than 10 percent of section depth.

Bending Stiffness (EI) = Computed Bending Moment / Curvature.
Position of neutral axis is measured from edge of compression side of pile.
Compressive stresses and strains are positive in sign.
Tensile stresses and strains are negative in sign.

Axial Thrust Force = 0.000 kips

Bending Max Conc Curvature rad/in.	Bending Max Steel Stress ksi	Bending Moment Stress in-kip	Run Msg	Stiffness kip-in2	Depth to N Axis in	Max Comp Strain in/in	Max Tens Strain in/in
0.00000125	94.3912760	75513021.		12.0001610	0.00001500	-0.00001500	
0.0627343	0.2914558						
0.00000250	188.3222133	75328885.		12.0001616	0.00003000	-0.00003000	
0.1249728	0.5829117						
0.00000375	281.7928118	75144750.		12.0001622	0.00004500	-0.00004500	
0.1867155	0.8743676						
0.00000500	374.8030716	74960614.		12.0001627	0.00006000	-0.00006000	
0.2479623	1.1658236						
0.00000625	467.3529926	74776479.		12.0001633	0.00007500	-0.00007500	
0.3087133	1.4572796						
0.00000750	559.4425749	74592343.		12.0001639	0.00009000	-0.00009000	

```
 0.3689684     1.7487357
0.00000875   651.0718185     74408208.    12.0001645     0.0001050     -0.000105
 0.4287278     2.0401918
0.00001000   651.0718185     65107182.     7.0895135    0.00007090     -0.000169
 0.2901283    -3.755641 C
0.00001125   651.0718185     57873051.     7.0920465    0.00007979     -0.000190
 0.3257422    -4.224270 C
0.00001250   651.0718185     52085745.     7.0945856    0.00008868     -0.000211
 0.3612103    -4.692713 C
0.00001375   651.0718185     47350678.     7.0971310    0.00009759     -0.000232
 0.3965323    -5.160969 C
0.00001500   651.0718185     43404788.     7.0996827     0.0001065     -0.000254
 0.4317079    -5.629038 C
0.00001625   651.0718185     40065958.     7.1022407     0.0001154     -0.000275
 0.4667368    -6.096919 C
0.00001750   651.0718185     37204104.     7.1048050     0.0001243     -0.000296
 0.5016187    -6.564611 C
0.00001875   651.0718185     34723830.     7.1073758     0.0001333     -0.000317
 0.5363533    -7.032114 C
0.00002000   651.0718185     32553591.     7.1099529     0.0001422     -0.000338
 0.5709404    -7.499427 C
0.00002125   651.0718185     30638674.     7.1125365     0.0001511     -0.000359
 0.6053796    -7.966549 C
0.00002250   651.0718185     28936525.     7.1151266     0.0001601     -0.000380
 0.6396707    -8.433480 C
0.00002375   651.0718185     27413550.     7.1177232     0.0001690     -0.000401
 0.6738134    -8.900218 C
0.00002500   651.0718185     26042873.     7.1203263     0.0001780     -0.000422
 0.7078073    -9.366763 C
0.00002625   651.0718185     24802736.     7.1229361     0.0001870     -0.000443
 0.7416522    -9.833115 C
0.00002750   651.0718185     23675339.     7.1255524     0.0001960     -0.000464
 0.7753477   -10.299272 C
0.00002875   651.0718185     22645976.     7.1281754     0.0002049     -0.000485
 0.8088937   -10.765234 C
0.00003000   651.0718185     21702394.     7.1308051     0.0002139     -0.000506
 0.8422897   -11.230999 C
0.00003125   651.0718185     20834298.     7.1334415     0.0002229     -0.000527
 0.8755354   -11.696569 C
0.00003250   651.0718185     20032979.     7.1360847     0.0002319     -0.000548
 0.9086306   -12.161940 C
0.00003375   668.2431395     19799797.     7.1387346     0.0002409     -0.000569
 0.9415750   -12.627113 C
0.00003500   692.6630973     19790374.     7.1413914     0.0002499     -0.000590
 0.9743682   -13.092088 C
0.00003625   717.0587367     19780931.     7.1440550     0.0002590     -0.000611
 1.0070099   -13.556862 C
0.00003750   741.4299750     19771466.     7.1467256     0.0002680     -0.000632
 1.0394998   -14.021436 C
0.00003875   765.7767291     19761980.     7.1494031     0.0002770     -0.000653
```

 1.0718376   -14.485808 C
0.00004000   790.0989150   19752473.   7.1520875   0.0002861   -0.000674
 1.1040230   -14.949978 C
0.00004125   814.3964486   19742944.   7.1547790   0.0002951   -0.000695
 1.1360556   -15.413946 C
0.00004250   838.6692449   19733394.   7.1574775   0.0003042   -0.000716
 1.1679352   -15.877709 C
0.00004375   862.9172184   19723822.   7.1601831   0.0003133   -0.000737
 1.1996614   -16.341268 C
0.00004500   887.1402832   19714229.   7.1628958   0.0003223   -0.000758
 1.2312339   -16.804621 C
0.00004625   911.3383526   19704613.   7.1656157   0.0003314   -0.000779
 1.2626523   -17.267768 C
0.00004750   935.5113395   19694976.   7.1683427   0.0003405   -0.000800
 1.2939164   -17.730708 C
0.00004875   959.6591560   19685316.   7.1710770   0.0003496   -0.000820
 1.3250258   -18.193440 C
0.00005125   1008.   19665930.   7.1765675   0.0003678   -0.000862
 1.3867791   -19.118276 C
0.00005375   1056.   19646455.   7.1820875   0.0003860   -0.000904
 1.4479097   -20.042271 C
0.00005625   1104.   19626889.   7.1876372   0.0004043   -0.000946
 1.5084148   -20.965417 C
0.00005875   1152.   19607231.   7.1932169   0.0004226   -0.000987
 1.5682916   -21.887707 C
0.00006125   1200.   19587481.   7.1988271   0.0004409   -0.001029
 1.6275373   -22.809133 C
0.00006375   1247.   19567638.   7.2044680   0.0004593   -0.001071
 1.6861492   -23.729690 C
0.00006625   1295.   19547700.   7.2101401   0.0004777   -0.001112
 1.7441245   -24.649368 C
0.00006875   1343.   19527666.   7.2158436   0.0004961   -0.001154
 1.8014601   -25.568162 C
0.00007125   1390.   19507537.   7.2215789   0.0005145   -0.001195
 1.8581533   -26.486062 C
0.00007375   1437.   19487310.   7.2273464   0.0005330   -0.001237
 1.9142010   -27.403063 C
0.00007625   1484.   19466984.   7.2331464   0.0005515   -0.001278
 1.9696002   -28.319155 C
0.00007875   1531.   19446559.   7.2389793   0.0005701   -0.001320
 2.0243480   -29.234331 C
0.00008125   1578.   19426034.   7.2448456   0.0005886   -0.001361
 2.0784413   -30.148582 C
0.00008375   1625.   19405406.   7.2507456   0.0006072   -0.001403
 2.1318768   -31.061901 C
0.00008625   1672.   19384676.   7.2566796   0.0006259   -0.001444
 2.1846516   -31.974280 C
0.00008875   1719.   19363842.   7.2626481   0.0006446   -0.001485
 2.2367624   -32.885709 C
0.00009125   1765.   19342903.   7.2686516   0.0006633   -0.001527

```
 2.2882060    -33.796180 C
0.00009375         1811.     19321858.     7.2746903     0.0006820     -0.001568
 2.3389790    -34.705685 C
0.00009625         1858.     19300705.     7.2807649     0.0007008     -0.001609
 2.3890782    -35.614215 C
0.00009875         1904.     19279444.     7.2868756     0.0007196     -0.001650
 2.4385002    -36.521760 C
 0.0001013         1950.     19258072.     7.2930229     0.0007384     -0.001692
 2.4872416    -37.428311 C
 0.0001038         1996.     19236590.     7.2992073     0.0007573     -0.001733
 2.5352989    -38.333860 C
 0.0001063         2042.     19214995.     7.3054293     0.0007762     -0.001774
 2.5826687    -39.238396 C
 0.0001088         2087.     19193286.     7.3116892     0.0007951     -0.001815
 2.6293473    -40.141910 C
 0.0001113         2133.     19171462.     7.3179876     0.0008141     -0.001856
 2.6753312    -41.044392 C
 0.0001138         2178.     19149550.     7.3241825     0.0008331     -0.001897
 2.7205777    -41.946303 C
 0.0001163         2224.     19127536.     7.3303481     0.0008522     -0.001938
 2.7651031    -42.847414 C
 0.0001188         2269.     19105407.     7.3365511     0.0008712     -0.001979
 2.8089215    -43.747502 C
 0.0001213         2314.     19083162.     7.3427920     0.0008903     -0.002020
 2.8520293    -44.646557 C
 0.0001238         2359.     19060800.     7.3490712     0.0009094     -0.002061
 2.8944227    -45.544570 C
 0.0001263         2404.     19038318.     7.3553892     0.0009286     -0.002101
 2.9360979    -46.441531 C
 0.0001288         2448.     19015716.     7.3617466     0.0009478     -0.002142
 2.9770511    -47.337428 C
 0.0001313         2493.     18992993.     7.3681437     0.0009671     -0.002183
 3.0172784    -48.232253 C
 0.0001338         2537.     18970146.     7.3745812     0.0009864     -0.002224
 3.0567757    -49.125993 C
 0.0001363         2582.     18947174.     7.3810596     0.0010057     -0.002264
 3.0955391    -50.018638 C
 0.0001388         2626.     18924076.     7.3875793     0.0010250     -0.002305
 3.1335644    -50.910177 C
 0.0001413         2670.     18900850.     7.3941411     0.0010444     -0.002346
 3.1708476    -51.800599 C
 0.0001438         2714.     18877495.     7.4007453     0.0010639     -0.002386
 3.2073843    -52.689893 C
 0.0001463         2757.     18854009.     7.4073926     0.0010833     -0.002427
 3.2431704    -53.578046 C
 0.0001488         2801.     18830390.     7.4140836     0.0011028     -0.002467
 3.2782014    -54.465046 C
 0.0001588         2974.     18734553.     7.4412964     0.0011813     -0.002629
 3.4106856    -58.001281 C
 0.0001688         3144.     18628437.     7.4681982     0.0012603     -0.002790
```

```
3.5304632    -60.000000 CY
0.0001788         3292.     18417289.     7.4816603     0.0013373     -0.002953
3.6342608    -60.000000 CY
0.0001888         3413.     18084564.     7.4775119     0.0014114     -0.003119
3.7217028    -60.000000 CY
0.0001988         3497.     17592713.     7.4477312     0.0014802     -0.003290
3.7922432    -60.000000 CY
0.0002088         3570.     17102814.     7.4167826     0.0015483     -0.003462
3.8518073    -60.000000 CY
0.0002188         3643.     16652143.     7.3909242     0.0016168     -0.003633
3.9016624    -60.000000 CY
0.0002288         3714.     16235380.     7.3695705     0.0016858     -0.003804
3.9415935    -60.000000 CY
0.0002388         3782.     15839155.     7.3503549     0.0017549     -0.003975
3.9712114    -60.000000 CY
0.0002488         3834.     15414182.     7.3226596     0.0018215     -0.004148
3.9899372    -60.000000 CY
0.0002588         3870.     14955602.     7.2830376     0.0018845     -0.004326
3.9987879    -60.000000 CY
0.0002688         3898.     14504756.     7.2421848     0.0019463     -0.004504
3.9984871    -60.000000 CY
0.0002788         3925.     14082272.     7.2057303     0.0020086     -0.004681
3.9977312    -60.000000 CY
0.0002888         3952.     13686075.     7.1734635     0.0020713     -0.004859
3.9962952    -60.000000 CY
0.0002988         3977.     13313600.     7.1449562     0.0021346     -0.005035
3.9999920    -60.000000 CY
0.0003088         4002.     12962501.     7.1198892     0.0021983     -0.005212
3.9994825    -60.000000 CY
0.0003188         4026.     12631049.     7.0978405     0.0022624     -0.005388
3.9977653    -60.000000 CY
0.0003288         4049.     12317614.     7.0783772     0.0023270     -0.005563
3.9978694    -60.000000 CY
0.0003388         4072.     12020306.     7.0605074     0.0023917     -0.005738
3.9994066    -60.000000 CY
0.0003488         4094.     11738246.     7.0449332     0.0024569     -0.005913
3.9963345    -60.000000 CY
0.0003588         4115.     11470313.     7.0313942     0.0025225     -0.006087
3.9998984    -60.000000 CY
0.0003688         4136.     11215201.     7.0198370     0.0025886     -0.006261
3.9971944    -60.000000 CY
0.0003788         4156.     10972130.     7.0097695     0.0026550     -0.006435
3.9999823    -60.000000 CY
0.0003888         4174.     10737994.     7.0003740     0.0027214     -0.006609
3.9970500    -60.000000 CY
0.0003988         4190.     10508927.     6.9893271     0.0027870     -0.006783
3.9999202    -60.000000 CY
0.0004088         4204.     10283865.     6.9764958     0.0028516     -0.006958
3.9952971    -60.000000 CY
0.0004188         4215.     10064652.     6.9626196     0.0029156     -0.007134
```

```
    3.9992445    -60.000000 CY
    0.0004288         4222.      9847056.     6.9453771     0.0029778     -0.007312
    3.9965169    -60.000000 CY
    0.0004388         4228.      9637072.     6.9285964     0.0030399     -0.007490
    3.9963090    -60.000000 CYT
    0.0004488         4232.      9430126.     6.9092170     0.0031005     -0.007669
    3.9993356    -60.000000 CYT
    0.0004588         4235.      9231653.     6.8910223     0.0031613     -0.007849
    3.9972298    -60.000000 CYT
    0.0004688         4238.      9041089.     6.8740748     0.0032222     -0.008028
    3.9944442    -60.000000 CYT
    0.0004788         4241.      8858275.     6.8581617     0.0032833     -0.008207
    3.9982746    -60.000000 CYT
    0.0004888         4244.      8682730.     6.8432265     0.0033446     -0.008385
    3.9999299    -60.000000 CYT
    0.0004988         4246.      8513678.     6.8284705     0.0034057     -0.008564
    3.9927329    -60.000000 CYT
    0.0005088         4249.      8351012.     6.8143716     0.0034668     -0.008743
    3.9948307    -60.000000 CYT
    0.0005188         4251.      8194468.     6.8010897     0.0035281     -0.008922
    3.9982940    -60.000000 CYT
    0.0005288         4253.      8043697.     6.7885840     0.0035895     -0.009101
    3.9998885    -60.000000 CYT
    0.0005388         4255.      7898253.     6.7769862     0.0036511     -0.009279
    3.9939551    -60.000000 CYT
    0.0005488         4257.      7757930.     6.7661287     0.0037129     -0.009457
    3.9922538    -60.000000 CYT
    0.0006088         4257.      6993288.     6.7655260     0.0041185     -0.010491
    3.9988266    -60.000000 CYT


-------------------------------------------------------------------------------
   Summary of Results for Nominal Moment Capacity for Section 1
-------------------------------------------------------------------------------

Moment values interpolated at maximum compressive strain = 0.003
or maximum developed moment if pile fails at smaller strains.

 Load           Axial Thrust        Nominal Mom. Cap.      Max. Comp.      Max.
Tens.
  No.              kips                 in-kip               Strain
Strain
 ----         ----------------     ------------------     ------------
------------
   1                0.000              4224.189           0.00300000
-0.00737569

Note that the values of moment capacity in the table above are not
factored by a strength reduction factor (phi-factor).
```

In ACI 318, the value of the strength reduction factor depends on whether the transverse reinforcing steel bars are tied hoops (0.65) or spirals (0.75).

The above values should be multiplied by the appropriate strength reduction factor to compute ultimate moment capacity according to ACI 318, or the value required by the design standard being followed.

The following table presents factored moment capacities and corresponding bending stiffnesses computed for common resistance factor values used for reinforced concrete sections.

Axial Load No.	Resist. Factor	Nominal Ax. Thrust kips	Nominal Moment Cap in-kips	Ult. (Fac) Ax. Thrust kips	Ult. (Fac) Moment Cap in-kips	Bend. Stiff. at Ult Mom kip-in^2
1	0.65	0.0000	4224.	0.0000	2746.	18860275.
1	0.75	0.0000	4224.	0.0000	3168.	18593479.
1	0.90	0.0000	4224.	0.0000	3802.	15676426.

Layering Correction Equivalent Depths of Soil & Rock Layers

Layer No.	Top of Layer Below Pile Head ft	Equivalent Top Depth Below Grnd Surf ft	Same Layer Type As Layer Above	Layer is Rock or is Below Rock Layer	F0 Integral for Layer lbs	F1 Integral for Layer lbs
1	0.00	0.00	N.A.	No	0.00	11790.
2	4.0000	4.0000	Yes	No	11790.	69203.
3	11.5000	8.6139	Yes	No	80993.	182150.
4	17.0000	17.0000	No	Yes	N.A.	N.A.

Notes: The F0 integral of Layer n+1 equals the sum of the F0 and F1 integrals for Layer n. Layering correction equivalent depths are computed only for soil types with both shallow-depth and deep-depth expressions for peak lateral load transfer. These soil types are soft and stiff clays, non-liquefied sands, and cemented c-phi soil.

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

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

Shear force at pile head = 1913.2 lbs
Applied moment at pile head = 0.0 in-lbs
Axial thrust load on pile head = 0.0 lbs

Depth X	Deflect. y	Bending Moment	Shear Force	Slope S	Total Stress	Bending Stiffness	Soil Res. Es*H	Soil Spr. Lat. Load	Distrib. p
feet	inches	in-lbs	lbs	radians	psi*	lb-in^2	lb/inch	lb/inch	lb/inch
0.00	0.02998	2.91E-06	1913.	-2.59E-04	0.00	7.55E+10	0.00	0.00	0.00
0.2000	0.02936	4592.	1911.	-2.59E-04	0.00	7.55E+10	-1.762	144.0000	0.00
0.4000	0.02874	9173.	1905.	-2.58E-04	0.00	7.55E+10	-3.449	288.0000	0.00
0.6000	0.02812	13735.	1895.	-2.58E-04	0.00	7.55E+10	-5.062	432.0000	0.00
0.8000	0.02750	18268.	1881.	-2.57E-04	0.00	7.55E+10	-6.601	576.0000	0.00
1.0000	0.02689	22762.	1863.	-2.57E-04	0.00	7.55E+10	-8.066	720.0000	0.00
1.2000	0.02627	27211.	1842.	-2.56E-04	0.00	7.55E+10	-9.458	864.0000	0.00
1.4000	0.02566	31604.	1818.	-2.55E-04	0.00	7.55E+10	-10.776	1008.	0.00
1.6000	0.02505	35936.	1790.	-2.54E-04	0.00	7.55E+10	-12.023	1152.	0.00
1.8000	0.02444	40198.	1760.	-2.53E-04	0.00	7.55E+10	-13.197	1296.	0.00
2.0000	0.02383	44385.	1727.	-2.51E-04	0.00	7.55E+10	-14.300	1440.	0.00
2.2000	0.02323	48489.	1692.	-2.50E-04	0.00	7.55E+10	-15.333	1584.	0.00
2.4000	0.02263	52504.	1654.	-2.48E-04	0.00	7.55E+10	-16.297	1728.	0.00
2.6000	0.02204	56426.	1613.	-2.47E-04	0.00	7.55E+10			

-17.191 1872. 0.00
2.8000 0.02145 60249. 1571. -2.45E-04 0.00 7.55E+10
-18.019 2016. 0.00
3.0000 0.02087 63968. 1527. -2.43E-04 0.00 7.55E+10
-18.779 2160. 0.00
3.2000 0.02029 67578. 1481. -2.41E-04 0.00 7.55E+10
-19.474 2304. 0.00
3.4000 0.01971 71077. 1434. -2.38E-04 0.00 7.55E+10
-20.104 2448. 0.00
3.6000 0.01914 74460. 1385. -2.36E-04 0.00 7.55E+10
-20.672 2592. 0.00
3.8000 0.01858 77724. 1334. -2.34E-04 0.00 7.55E+10
-21.177 2736. 0.00
4.0000 0.01802 80865. 1288. -2.31E-04 0.00 7.55E+10
-17.298 2304. 0.00
4.2000 0.01747 83908. 1246. -2.29E-04 0.00 7.55E+10
-17.606 2419. 0.00
4.4000 0.01692 86848. 1204. -2.26E-04 0.00 7.55E+10
-17.869 2534. 0.00
4.6000 0.01638 89686. 1161. -2.23E-04 0.00 7.55E+10
-18.086 2650. 0.00
4.8000 0.01585 92420. 1117. -2.20E-04 0.00 7.55E+10
-18.260 2765. 0.00
5.0000 0.01533 95048. 1073. -2.17E-04 0.00 7.55E+10
-18.391 2880. 0.00
5.2000 0.01481 97571. 1029. -2.14E-04 0.00 7.55E+10
-18.480 2995. 0.00
5.4000 0.01430 99987. 984.4603 -2.11E-04 0.00 7.55E+10
-18.530 3110. 0.00
5.6000 0.01379 102296. 939.9765 -2.08E-04 0.00 7.55E+10
-18.540 3226. 0.00
5.8000 0.01330 104499. 895.5117 -2.05E-04 0.00 7.55E+10
-18.514 3341. 0.00
6.0000 0.01281 106595. 851.1541 -2.01E-04 0.00 7.55E+10
-18.451 3456. 0.00
6.2000 0.01233 108584. 806.9885 -1.98E-04 0.00 7.55E+10
-18.354 3571. 0.00
6.4000 0.01186 110468. 763.0962 -1.94E-04 0.00 7.55E+10
-18.223 3686. 0.00
6.6000 0.01140 112247. 719.5554 -1.91E-04 0.00 7.55E+10
-18.061 3802. 0.00
6.8000 0.01095 113922. 676.4406 -1.87E-04 0.00 7.54E+10
-17.868 3917. 0.00
7.0000 0.01050 115494. 633.8229 -1.83E-04 0.00 7.54E+10
-17.647 4032. 0.00
7.2000 0.01007 116964. 591.7701 -1.80E-04 0.00 7.54E+10
-17.397 4147. 0.00
7.4000 0.00964 118334. 550.3462 -1.76E-04 0.00 7.54E+10
-17.122 4262. 0.00
7.6000 0.00922 119606. 509.6119 -1.72E-04 0.00 7.54E+10

-16.823 4378. 0.00
7.8000 0.00881 120781. 469.6241 -1.68E-04 0.00 7.54E+10
-16.500 4493. 0.00
8.0000 0.00841 121860. 430.4365 -1.65E-04 0.00 7.54E+10
-16.156 4608. 0.00
8.2000 0.00802 122847. 392.0988 -1.61E-04 0.00 7.54E+10
-15.792 4723. 0.00
8.4000 0.00764 123742. 354.6574 -1.57E-04 0.00 7.54E+10
-15.409 4838. 0.00
8.6000 0.00727 124549. 318.1550 -1.53E-04 0.00 7.54E+10
-15.009 4954. 0.00
8.8000 0.00691 125269. 282.6308 -1.49E-04 0.00 7.54E+10
-14.594 5069. 0.00
9.0000 0.00656 125906. 248.1204 -1.45E-04 0.00 7.54E+10
-14.165 5184. 0.00
9.2000 0.00621 126460. 214.6558 -1.41E-04 0.00 7.54E+10
-13.723 5299. 0.00
9.4000 0.00588 126936. 182.2655 -1.37E-04 0.00 7.54E+10
-13.269 5414. 0.00
9.6000 0.00556 127335. 150.9743 -1.33E-04 0.00 7.54E+10
-12.807 5530. 0.00
9.8000 0.00524 127661. 120.8036 -1.29E-04 0.00 7.54E+10
-12.336 5645. 0.00
10.0000 0.00494 127915. 91.7714 -1.25E-04 0.00 7.54E+10
-11.858 5760. 0.00
10.2000 0.00465 128101. 63.8919 -1.21E-04 0.00 7.54E+10
-11.375 5875. 0.00
10.4000 0.00436 128222. 37.1761 -1.16E-04 0.00 7.54E+10
-10.888 5990. 0.00
10.6000 0.00409 128280. 11.6314 -1.12E-04 0.00 7.54E+10
-10.399 6106. 0.00
10.8000 0.00382 128278. -12.738 -1.08E-04 0.00 7.54E+10
-9.909 6221. 0.00
11.0000 0.00357 128218. -35.932 -1.04E-04 0.00 7.54E+10
-9.419 6336. 0.00
11.2000 0.00332 128105. -57.953 -1.00E-04 0.00 7.54E+10
-8.931 6451. 0.00
11.4000 0.00309 127940. -78.807 -9.61E-05 0.00 7.54E+10
-8.447 6566. 0.00
11.6000 0.00286 127727. -148.694 -9.20E-05 0.00 7.54E+10
-49.793 41760. 0.00
11.8000 0.00265 127227. -264.641 -8.79E-05 0.00 7.54E+10
-46.830 42480. 0.00
12.0000 0.00244 126457. -373.532 -8.39E-05 0.00 7.54E+10
-43.913 43200. 0.00
12.2000 0.00224 125434. -475.485 -7.99E-05 0.00 7.54E+10
-41.048 43920. 0.00
12.4000 0.00206 124174. -570.637 -7.59E-05 0.00 7.54E+10
-38.244 44640. 0.00
12.6000 0.00188 122695. -659.139 -7.20E-05 0.00 7.54E+10

```
-35.507     45360.       0.00
   12.8000    0.00171    121010.   -741.160  -6.81E-05       0.00   7.54E+10
-32.844     46080.       0.00
   13.0000    0.00155    119137.   -816.884  -6.43E-05       0.00   7.54E+10
-30.260     46800.       0.00
   13.2000    0.00140    117089.   -886.508  -6.05E-05       0.00   7.54E+10
-27.760     47520.       0.00
   13.4000    0.00126    114882.   -950.242  -5.68E-05       0.00   7.54E+10
-25.351     48240.       0.00
   13.6000    0.00113    112528.     -1008.  -5.32E-05       0.00   7.55E+10
-23.036     48960.       0.00
   13.8000    0.00101    110042.     -1061.  -4.97E-05       0.00   7.55E+10
-20.819     49680.       0.00
   14.0000   8.91E-04    107436.     -1108.  -4.62E-05       0.00   7.55E+10
-18.705     50400.       0.00
   14.2000   7.84E-04    104722.     -1151.  -4.29E-05       0.00   7.55E+10
-16.697     51120.       0.00
   14.4000   6.85E-04    101912.     -1189.  -3.96E-05       0.00   7.55E+10
-14.797     51840.       0.00
   14.6000   5.94E-04     99016.     -1222.  -3.64E-05       0.00   7.55E+10
-13.008     52560.       0.00
   14.8000   5.10E-04     96046.     -1251.  -3.33E-05       0.00   7.55E+10
-11.332     53280.       0.00
   15.0000   4.34E-04     93011.     -1277.  -3.03E-05       0.00   7.55E+10
-9.770     54000.       0.00
   15.2000   3.65E-04     89919.     -1298.  -2.74E-05       0.00   7.55E+10
-8.325     54720.       0.00
   15.4000   3.03E-04     86779.     -1317.  -2.46E-05       0.00   7.55E+10
-6.997     55440.       0.00
   15.6000   2.47E-04     83599.     -1332.  -2.18E-05       0.00   7.55E+10
-5.786     56160.       0.00
   15.8000   1.98E-04     80385.     -1345.  -1.92E-05       0.00   7.55E+10
-4.694     56880.       0.00
   16.0000   1.55E-04     77145.     -1355.  -1.67E-05       0.00   7.55E+10
-3.718     57600.       0.00
   16.2000   1.18E-04     73883.     -1363.  -1.43E-05       0.00   7.55E+10
-2.860     58320.       0.00
   16.4000   8.61E-05     70605.     -1369.  -1.20E-05       0.00   7.55E+10
-2.118     59040.       0.00
   16.6000   5.99E-05     67314.     -1373.  -9.85E-06       0.00   7.55E+10
-1.492     59760.       0.00
   16.8000   3.88E-05     64015.     -1376.  -7.76E-06       0.00   7.55E+10
-0.979     60480.       0.00
   17.0000   2.26E-05     60711.     -2088.  -5.78E-06       0.00   7.55E+10
-592.721   6.28E+07       0.00
   17.2000   1.11E-05     53992.     -3482.  -3.96E-06       0.00   7.55E+10
-568.630   1.23E+08       0.00
   17.4000   3.65E-06     43998.     -4756.  -2.40E-06       0.00   7.55E+10
-493.036   3.24E+08       0.00
   17.6000  -4.32E-07     31164.     -5244.  -1.21E-06       0.00   7.55E+10
```

```
85.9169   4.77E+08       0.00
   17.8000  -2.14E-06     18824.     -4583.  -4.11E-07       0.00   7.55E+10
465.4239   5.23E+08       0.00
   18.0000  -2.41E-06      9166.     -3346.   3.34E-08       0.00   7.55E+10
564.8427   5.63E+08       0.00
   18.2000  -1.98E-06      2761.     -2062.   2.23E-07       0.00   7.55E+10
505.4331   6.13E+08       0.00
   18.4000  -1.34E-06   -732.145     -1015.   2.55E-07       0.00   7.55E+10
367.0904   6.59E+08       0.00
   18.6000  -7.53E-07     -2111.   -309.539   2.10E-07       0.00   7.55E+10
220.8910   7.04E+08       0.00
   18.8000  -3.29E-07     -2218.    78.9734   1.41E-07       0.00   7.55E+10
102.8692   7.50E+08       0.00
   19.0000  -7.51E-08     -1732.   232.2593   7.84E-08       0.00   7.55E+10
24.8691   7.95E+08       0.00
   19.2000   4.70E-08     -1103.   242.3275   3.33E-08       0.00   7.55E+10
-16.479   8.41E+08       0.00
   19.4000   8.50E-08   -568.961   184.8896   6.78E-09       0.00   7.55E+10
-31.386   8.86E+08       0.00
   19.6000   7.96E-08   -215.617   110.1640  -5.69E-09       0.00   7.55E+10
-30.886   9.32E+08       0.00
   19.8000   5.77E-08    -40.173    44.9202  -9.76E-09       0.00   7.55E+10
-23.484   9.77E+08       0.00
   20.0000   3.27E-08       0.00       0.00  -1.04E-08       0.00   7.55E+10
-13.949   5.11E+08       0.00
```

* This analysis computed pile response using nonlinear moment-curvature relationships. Values of total stress due to combined axial and bending stresses are computed only for elastic sections only and do not equal the actual stresses in concrete and steel. Stresses in concrete and steel may be interpolated from the output for nonlinear bending properties relative to the magnitude of bending moment developed in the pile.

Output Summary for Load Case No. 1:

Pile-head deflection	=	0.02998299 inches
Computed slope at pile head	=	-0.0002586 radians
Maximum bending moment	=	128280. inch-lbs
Maximum shear force	=	-5244. lbs
Depth of maximum bending moment	=	10.60000000 feet below pile head
Depth of maximum shear force	=	17.60000000 feet below pile head
Number of iterations	=	6
Number of zero deflection points	=	2

Summary of Pile-head Responses for Conventional Analyses

Definitions of Pile-head Loading Conditions:

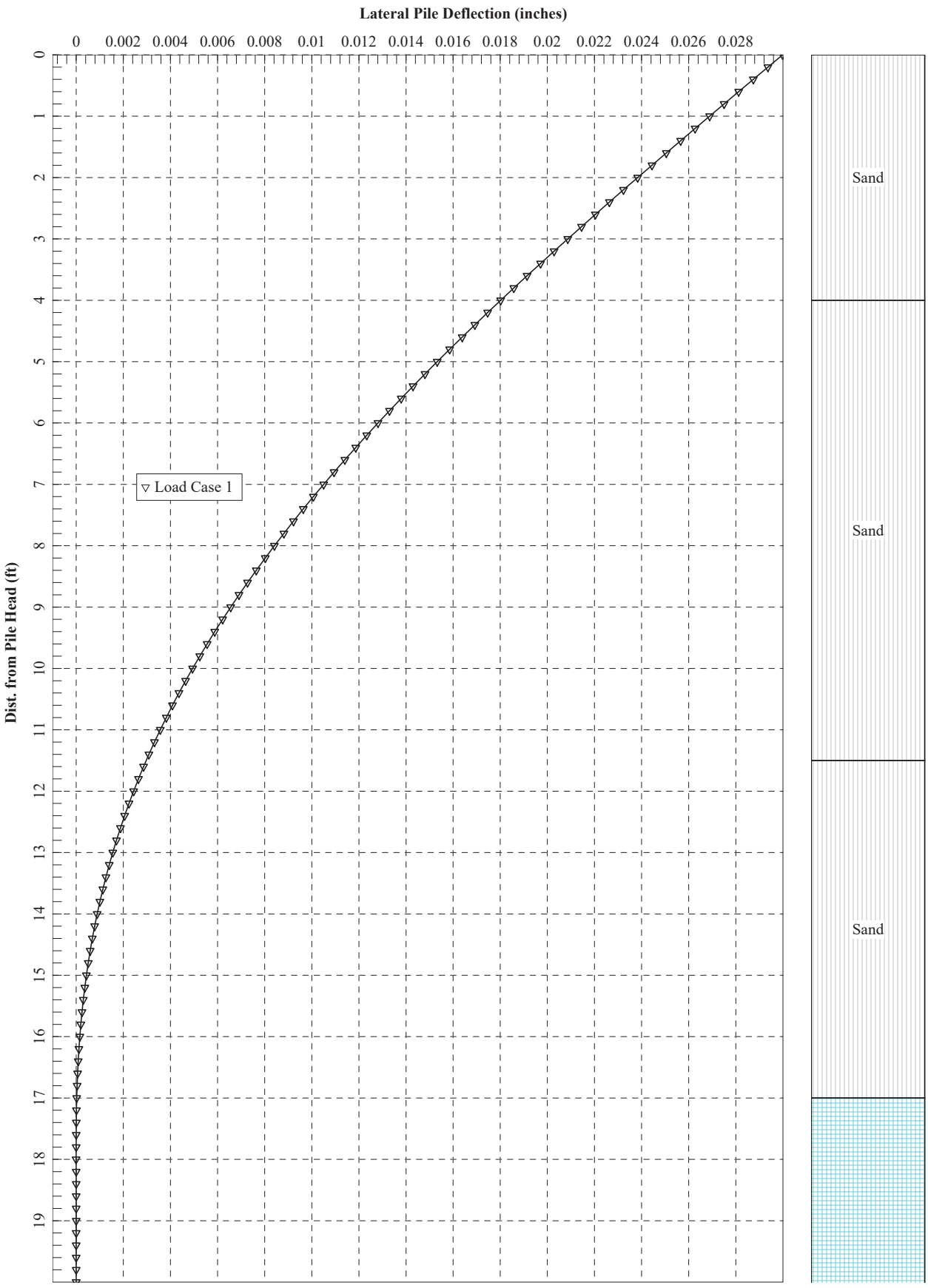
Load Type 1: Load 1 = Shear, V, lbs, and Load 2 = Moment, M, in-lbs
Load Type 2: Load 1 = Shear, V, lbs, and Load 2 = Slope, S, radians
Load Type 3: Load 1 = Shear, V, lbs, and Load 2 = Rot. Stiffness, R, in-lbs/rad.
Load Type 4: Load 1 = Top Deflection, y, inches, and Load 2 = Moment, M, in-lbs
Load Type 5: Load 1 = Top Deflection, y, inches, and Load 2 = Slope, S, radians

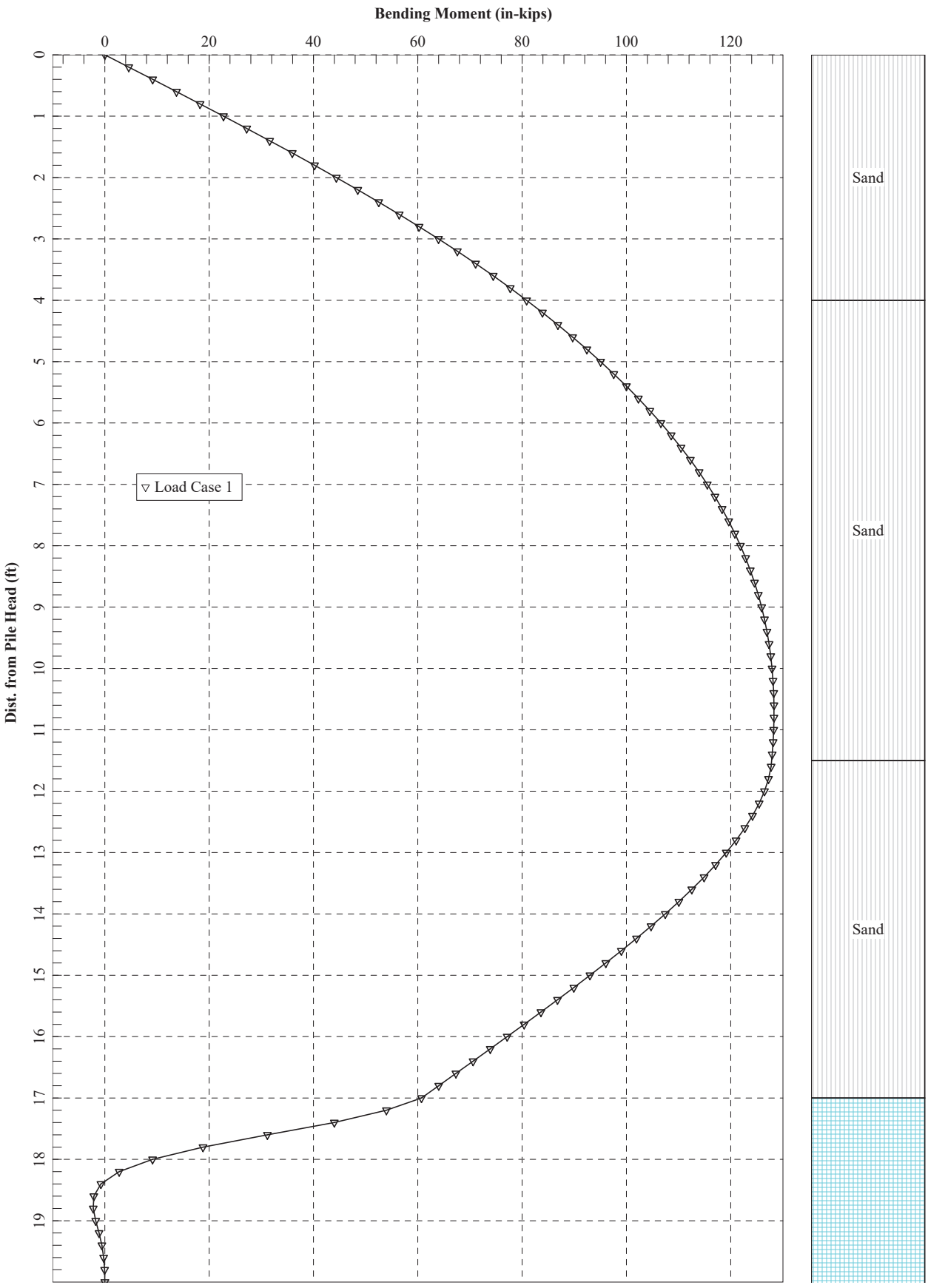
Load Case No.	Load Type 1	Load Pile-head 1	Load Type 2	Load Pile-head 2	Axial Loading lbs	Pile-head Deflection inches	Pile-head Rotation radians	Max Shear in Pile lbs	Max Moment in Pile in-lbs
1	V, lb	1913.	M, in-lb	0.00	0.00	0.02998	-2.59E-04	-5244.	128280.

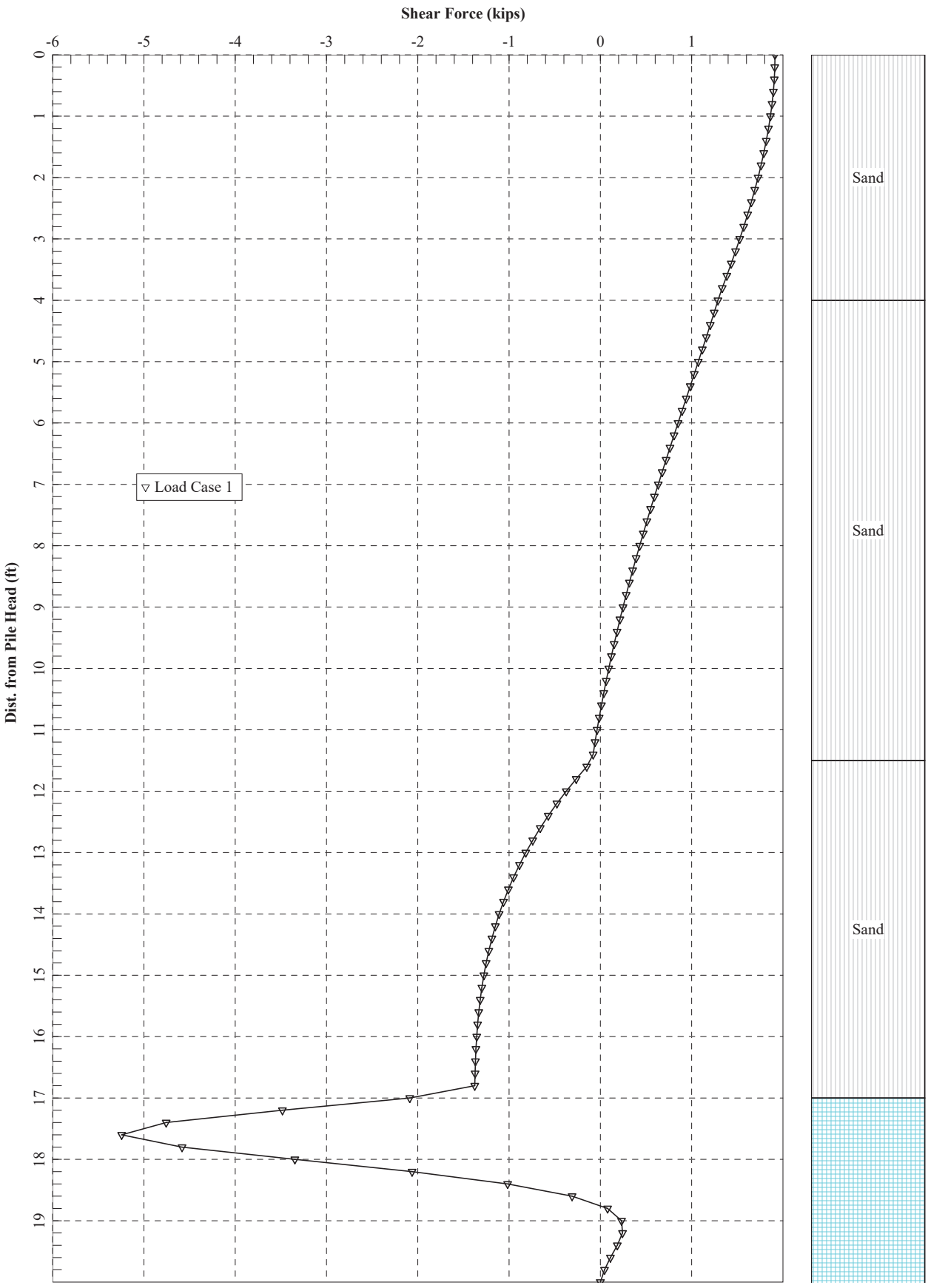
Maximum pile-head deflection = 0.0299829907 inches
Maximum pile-head rotation = -0.0002585886 radians = -0.014816 deg.

The analysis ended normally.

STR-I Load Case Anticipated Deflection (Caisson Bearing in Claystone) = 0.03 inches


Lateral Pile Deflection (inches)
0
0.002
0.004
0.006
0.008
0.01
0.012
0.014
0.016
0.018
0.02
0.022
0.024
0.026
0.028
Dist. from Pile Head (ft)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
Load Case 1
Sand
Sand
Sand


Bending Moment (in-kips)
0
20
40
60
80
100
120
Dist. from Pile Head (ft)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
Load Case 1
Sand
Sand
Sand


Shear Force (kips)
-6
-5
-4
-3
-2
-1
0
1
Dist. from Pile Head (ft)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
Load Case 1
Sand
Sand
Sand

Project:	SR88 Grade Crossing Caisson		**Sheet:**	1	**of**	3
	Tip Resistance		**By:**	SMC	**Date:**	7/18/23
Project: No.:	73937.06		**Chk:**	RHY	**Date:**	08/23

Tip Resistance in Soil - PennDOT & AASHTO

Purpose **:** Determine the Factored Tip Resistance of a Drilled Shaft bearing on Cohesionless Soil. Side resistance will be neglected

References **:** PENNDOT, Publication 15M Design Manual Part 4 Structures, DEC 2019

AASHTO LRFD Bridge Design Specifications, 8th Edition, 2017, Section 10.8.3.5.4c.

The factored resistance of drilled shafts, R_R, shall be taken as:

eglect R_s and ϕ_{qs} terms to neglect side sistance

$$R_R = \varphi R_n = \varphi_{qp} R_p + \varphi_{qs} R_s \qquad (10.8.3.5\text{-}1)$$

$$R_p = q_p A_p \qquad (10.8.3.5\text{-}2)$$

R_p = nominal shaft tip resistance (kips)

φ_{qp} = resistance factor for tip resistance specified in Table 10.5.5.2.4-1

q_p = unit tip resistance (ksf)

A_p = area of shaft tip (ft^2)

10.8.3.5.2c—Tip Resistance

The nominal tip resistance, q_p, in ksf, for drilled shafts in cohesionless soils by the method described in Brown et al. (2010) shall be taken as:

$$\text{If } N_{60} \le 50, \text{ then } q_p = 1.2 N_{60} \qquad (10.8.3.5.2c\text{-}1)$$

where:

N_{60} = average *SPT* blow count (corrected only for hammer efficiency) in the design zone under consideration (blows/ft)

The value of q_p in Eq. 10.8.3.5.2c-1 should be limited to 60 ksf, unless greater values can be justified though load test data.

Project:	SR88 Grade Crossing Caisson		***Sheet:***	1	***of*** 3
	Tip Resistance		***By:***	SMC	***Date:*** 7/18/23
Project: No.:	73937.06		***Chk:***	RHY	***Date:*** 08/23

Tip Resistance in Soil - PennDOT & AASHTO

Required Input Parameters:

D_S =	**2.0**	ft	*(Shaft Diameter)*
φ_{qp} =	**0.50**		*(Table 10.5.5.2.4-1 - see attached)*
N_{60} =	**50**	bpf	*(Average N value of residual claystone - corrected only for hammer efficiency)*
			(All residual N_{60} values in boring B-1 > 50 bpf, so use 50 bpf)

Computations:

1. Calculate A_p - the area of the shaft tip (ft^2)

A_p =	**3.1**	ft^2	

2. Calculate q_p - unit tip resistance (ksf)

q_p =	**60**	ksf	

3. Calculate Tip Resistance.

$R_p = q_p A_p$ =	**188**	kips	*(Unfactored Resistance)*
$\varphi_{qp} R_p$ =	**94**	kips	*(Factored Resistance)*

Factored Resistance = 94 kips > STR-I Axial Load = 1.91 kips

Unfactored Resistance = 188 kips > SER-I Axial Load = 1.53 kips

Project:	SR88 Grade Crossing Caisson		***Sheet:***	3	***of*** 3
	Tip Resistance		***By:***	SMC	***Date:*** 7/18/23
Project: No.:	73937.06		***Chk:***	RHY	***Date:*** 08/23

Drilled Shaft Resistance Factors - AASHTO/PennDOT

Table 10.5.5.2.4-1—Resistance Factors for Geotechnical Resistance of Drilled Shafts

Method/Soil/Condition			Resistance Factor
Nominal Axial Compressive Resistance of Single-Drilled Shafts, φ_{stat}	Side resistance in clay	α-method (Brown et al., 2010)	0.45
	Tip resistance in clay	Total Stress (Brown et al., 2010)	0.40
	Side resistance in sand	β-method (Brown et al., 2010)	0.55
	Tip resistance in sand	Brown et al. (2010)	0.50
	Side resistance in cohesive IGMs	Brown et al. (2010)	0.60
	Tip resistance in cohesive IGMs	Brown et al. (2010)	0.55
	Side resistance in rock	Kulhawy et al. (2005) Brown et al. (2010)	0.55
	Side resistance in rock	Carter and Kulhawy (1988)	0.50
	Tip resistance in rock	Canadian Geotechnical Society (1985) Pressuremeter Method (Canadian Geotechnical Society, 1985) Brown et al. (2010)	0.50
Block Failure, φ_{b1}	Clay		0.55
Uplift Resistance of Single-Drilled Shafts, φ_{up}	Clay	α-method (Brown et al., 2010)	0.35
	Sand	β-method (Brown et al., 2010)	0.45
	Rock	Kulhawy et al. (2005) Brown et al. (2010)	0.40
Group Uplift Resistance, φ_{ug}	Sand and clay		0.45
Horizontal Geotechnical Resistance of Single Shaft or Shaft Group	All materials		1.0
Static Load Test (compression), φ_{load}	All Materials		0.70
Static Load Test (uplift), φ_{upload}	All Materials		0.60

Project:	SR88 Grade Crossing Caisson		**Sheet:**	1	**of** 5
	Tip Resistance		**By:**	SMC	**Date:** 7/13/23
Project: No.:	73937.06		**Chk:**	RHY	**Date:** 08/23

Tip Resistance in Rock - PennDOT

Purpose **:** Determine the Factored Tip Resistance of a Drilled Shaft on Bedrock.

References **:** PENNDOT, Publication 15M Design Manual Part 4 Structures, DEC 2019
AASHTO LRFD Bridge Design Specifications, 8th Edition, 2017, Section 10.8.3.5.4c.

End-bearing for drilled shafts in rock may be taken as follows:

If the rock below the base of the shaft to a depth of $2.0B$ is jointed, the joints have random orientation, and the condition of the joints can be evaluated as:

$$q_p = A + q_u\left[m_b\left(\frac{A}{q_u}\right) + s\right]^a \qquad \text{(10.8.3.5.4c-2)}$$

$$A = \sigma'_{vb} + q_u\left[m_b\frac{(\sigma'_{v,b})}{q_u} + s\right]^a \qquad \text{(10.8.3.5.4c-3)}$$

10.8.3.5.4c Tip Resistance

The following shall replace Eqs. A10.8.3.5.4c-1 A10.8.3.5.4c-2 as follows:

$$q_p = [0.5'' / (0.04\ D_s)]\ (A + q_u\,[m_b\,(A/q_u) + s]^a) \qquad \text{(10.8.3.5.4c-2)}$$

Required Input Parameters:

D_S =	**2.0**	ft	*(Shaft Diameter)*
σ'_{vb} =	**2,650**	psf	*(Estimate based on Soil, Rock, & Groundwater Overburden)*
q_U =	**200**	psi	
φ_{qp} =	**0.50**		*(Table 10.5.5.2.4-1)*
GSI =	**40**		*(Estimate from Figure 10.4.6.4-1 or Figure 10.4.6.4-2)*
D =	**0.1**		*(Estimate Disturbance Factor as per Section 10.4.6.4)*
m_i =	**5**		*(Estimate from Table 10.4.6.4-1)*

Project:	SR88 Grade Crossing Caisson	**Sheet:**	2	**of**	5
	Tip Resistance	**By:**	SMC	**Date:**	7/13/23
Project: No.:	73937.06	**Chk:**	RHY	**Date:**	08/23

Tip Resistance in Rock - PennDOT

Computations:

1. First calculate empirically determined parameters from Hoek-Brown.

$$s = e^{\left(\frac{GSI-100}{9-3D}\right)} \qquad (10.4.6.4\text{-}2)$$

s = **0.0010**

$$a = \frac{1}{2} + \frac{1}{6}\left(e^{\frac{-GSI}{15}} - e^{\frac{-20}{3}}\right) \qquad (10.4.6.4\text{-}3)$$

a = **0.5114**

$$m_b = m_i e^{\left(\frac{GSI-100}{28-14D}\right)} \qquad (10.4.6.4\text{-}4)$$

m_b = **0.5240**

2. Calculate "A".

q_U =	**29**	ksf	
A =	**8.8**	ksf	

3. Calculate Tip Resistance.

q_p =	**10.5**	ksf	
A_p =	**3.1**	ft^2	
$R_p = q_p A_p$ =	**33**	kips	*(Unfactored Resistance)*
$\varphi_{qp} R_p$ =	**16**	kips	*(Factored Resistance)*

Factored Resistance = 16 kips > STR-I Axial Load = 1.91 kips

Unfactored Resistance = 33 kips > SER-I Axial Load = 1.53 kips

Project:	SR88 Grade Crossing Caisson		**Sheet:**	3	**of**	5
	Tip Resistance		**By:**	SMC	**Date:**	7/13/23
Project: No.:	73937.06		**Chk:**	RHY	**Date:**	08/23

Geological Strength Index (GSI)

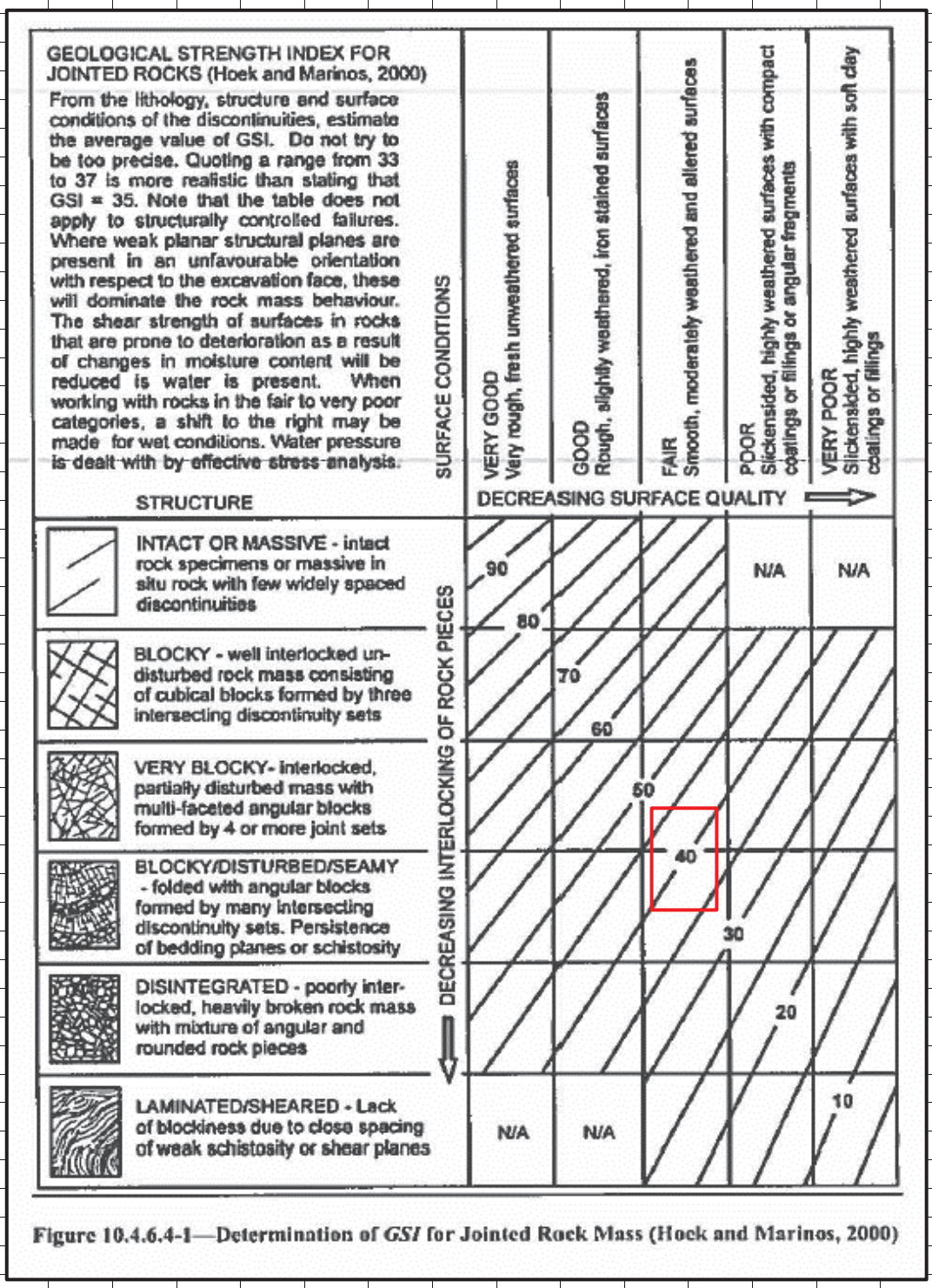


Figure 10.4.6.4-1—Determination of *GSI* for Jointed Rock Mass (Hoek and Marinos, 2000)

Project:	SR88 Grade Crossing Caisson		**Sheet:**	4	**of**	5
	Tip Resistance		**By:**	SMC	**Date:**	7/13/23
Project: No.:	73937.06		**Chk:**	RHY	**Date:**	08/23

Constant m_i by Rock Group

Table 10.4.6.4-1—Values of the Constant m_i by Rock Group (after Marinos and Hoek 2000; with updated values from Rocscience, Inc., 2007)

Rock type	Class	Group	Texture			
			Coarse	Medium	Fine	Very fine
SEDIMENTARY	Clastic		Conglomerate (21 ± 3) Breccia (19 ± 5)	Sandstone 17 ± 4	Siltstone 7 ± 2 Greywacke (18 ± 3)	Claystone 4 ± 2 Shale (6 ± 2) Marl (7 ± 2)
	Non-Clastic	Carbonates	Crystalline Limestone (12 ± 3)	Sparitic Limestone (10 ± 5)	Micritic Limestone (8 ± 3)	Dolomite (9 ± 3)
		Evaporites		Gypsum 10 ± 2	Anhydrite 12 ± 2	
		Organic				Chalk 7 ± 2
METAMORPHIC	Non Foliated		Marble 9 ± 3	Hornfels (19 ± 4)) Metasandstone (19 ± 3)	Quartzite 20 ± 3	
	Slightly foliated		Migmatite (29 ± 3)	Amphibolite 26 ± 6	Gneiss 28 ± 5	
	Foliated*			Schist (10 ± 3)	Phyllite (7 ± 3)	Slate 7 ± 4
IGNEOUS	Plutonic	Light	Granite 32 ± 3 Granodiorite (29 ± 3)	Diorite 25 ± 5		
		Dark	Gabbro 27 ± 3 Norite 20 ± 5	Dolerite (16 ± 5)		
	Hypabyssal		Porphyries (20 ± 5)		Diabase (15 ± 5)	Peridotite (25 ± 5)
	Volcanic	Lava		Rhyolite (25 ± 5) Andesite 25 ± 5	Dacite (25 ± 3)) Basalt (25 ± 5)	
		Pyroclastic	Agglomerate (19 ± 3)	Volcanic breccia (19 ± 5)	Tuff (13 ± 5)	

Project:	SR88 Grade Crossing Caisson		**Sheet:**	5	**of**	5
	Tip Resistance		**By:**	SMC	**Date:**	7/13/23
Project: No.:	73937.06		**Chk:**	RHY	**Date:**	08/23

Drilled Shaft Resistance Factors - AASHTO/PennDOT

Table 10.5.5.2.4-1—Resistance Factors for Geotechnical Resistance of Drilled Shafts

Method/Soil/Condition			Resistance Factor
Nominal Axial Compressive Resistance of Single-Drilled Shafts, φ_{stat}	Side resistance in clay	α-method (Brown et al., 2010)	0.45
	Tip resistance in clay	Total Stress (Brown et al., 2010)	0.40
	Side resistance in sand	β-method (Brown et al., 2010)	0.55
	Tip resistance in sand	Brown et al. (2010)	0.50
	Side resistance in cohesive IGMs	Brown et al. (2010)	0.60
	Tip resistance in cohesive IGMs	Brown et al. (2010)	0.55
	Side resistance in rock	Kulhawy et al. (2005) Brown et al. (2010)	0.55
	Side resistance in rock	Carter and Kulhawy (1988)	0.50
	Tip resistance in rock	Canadian Geotechnical Society (1985) Pressuremeter Method (Canadian Geotechnical Society, 1985) Brown et al. (2010)	0.50
Block Failure, φ_{bl}	Clay		0.55
Uplift Resistance of Single-Drilled Shafts, φ_{up}	Clay	α-method (Brown et al., 2010)	0.35
	Sand	β-method (Brown et al., 2010)	0.45
	Rock	Kulhawy et al. (2005) Brown et al. (2010)	0.40
Group Uplift Resistance, φ_{ug}	Sand and clay		0.45
Horizontal Geotechnical Resistance of Single Shaft or Shaft Group	All materials		1.0
Static Load Test (compression), φ_{load}	All Materials		0.70
Static Load Test (uplift), φ_{upload}	All Materials		0.60

LOADS

MARKOSKY
3689 Route 711 • Ligonier, PA 15658
724.238.4138 • www.markosky.com
COLLABORATIVE ENGINEERING

JOB 21-056E Route 88 Grade Crossing
SHEET NO. 3 OF 5
CALCULATED BY TJH DATE 1/19/2023
CHECKED BY BKL DATE 1/25/2023

Wind Forces (9'-0" Gate Arm)

- See included sketches for coordinates and force nomenclature

A_y =	33	sf	(exposed area in y-direction)
W_y =	1188.23	lb	(wind force in y-direction)
Moment Arm =	8.00	ft	
M_x =	9505.84	lb-ft	(moment about x-axis, caused by wind loading in y-direction)
A_x =	16	sf	(exposed area in x-direction)
W_x =	576.11	lb	(wind force in x-direction)
Moment Arm =	8.00	ft	
M_y =	4608.89	lb-ft	(moment about y-axis, caused by wind loading in x-direction)
A_a =	3	sf	(exposed area of gate arm)
W_a =	108.02	lb	(wind force along gate arm)
Moment Arm =	5.000	ft	
M_z =	540.10	lb-ft	(moment about z-axis, caused by wind loading along gate arm)

Reaction Summary (Strength I) USE MAX

- Apply Load Factors for Strength I Load Combination in accordance with AASHTO Table 3.4-1:
  - 1.25 Factor for Dead (DC) Load
  - No wind load included in Strength I loading case

vertical load only

Reaction	Description	Gate Arm Length			
		23'-0"	21'-0"	12'-0"	9'-0"
Rz (lbs)	Reaction at baseplate due to axial loading in z-direction	1913.25	1644.00	1210.13	1204.50

Reaction Summary (Service I)

- Assume moment due to gate arm weight is negligible compared to moment due to counterweight
- Apply Load Factors for Service I Load Combination in accordance with AASHTO Table 3.4-1:
  - 1.00 Factor for Dead (DC) Load
  - 1.00 Factor for Wind (W) Load

Reaction	Description	Gate Arm Length			
		23'-0"	21'-0"	12'-0"	9'-0"
Rx (lbs)	Reaction at baseplate due to wind loading in x-direction	576.11	576.11	576.11	576.11
Ry (lbs)	Reaction at baseplate due to wind loading in y-direction	1440.28	1368.27	1224.24	1188.23
Rz (lbs)	Reaction at baseplate due to axial loading in z-direction	1530.60	1315.20	968.10	963.60
Mx (lb-ft)	Moment about baseplate due to wind loading in y-direction	12962.51	16419.19	9793.90	9505.84
My (lb-ft)	Moment about baseplate due to wind loading in x-direction	5185.01	6913.34	4608.89	4608.89
Mz (lb-ft)	Torsion about baseplate due to wind loading on gate arm in y-direction	4091.29	3312.64	972.19	540.10

MARKOSKY
3689 Route 711 • Ligonier, PA 15658
724.238.4138 • www.markosky.com
COLLABORATIVE ENGINEERING

JOB 21-056E Route 88 Grade Crossing
SHEET NO. 4 OF 5
CALCULATED BY TJH DATE 1/19/2023
CHECKED BY BKL DATE 1/25/2023

Combined Forces Summary (Service I)

- Assume moment due to gate arm weight is negligible compared to moment due to counterweight
- Apply Load Factors for Service I Load Combination in accordance with AASHTO Table 3.4-1:
  - 1.00 Factor for Dead (DC) Load
  - 1.00 Factor for Wind (W) Load

design for max only

Description	Gate Arm Length			
	23'-0"	21'-0"	12'-0"	9'-0"
Shear (lbs)	1551.23	1484.61	1353.02	1320.53
Moment (lb-ft)	13961.06	17815.27	10824.16	10564.23
Axial (lbs)	1530.60	1315.20	968.10	963.60
Torsion (lb-ft)	4091.29	3312.64	972.19	540.10

BOWLES
Foundation Analysis and Design, 1996.

Table Empirical values for ϕ, D_r, and unit weight of granular soils based on the standard penetration number with corrections for depth and for fine saturated sands

Description	Very loose	Loose	Medium	Dense	Very dense
Relative density D_r*	0 — 0.15	0.35	0.65	0.85 — 1.00	
Standard penetration no. N	4	10	30	50	
Approx. angle of internal friction ϕ°†	25°–30°	27–32°	30–35°	35–40°	38–43°
Approx. range of moist unit weight, γ, pcf (kN/m³)	70–100‡ (11–16)		90–115 (14–18)	110–130 (17–20)	110–140 (17–22) / 130–150 (20–23)

* USBR [Gibbs and Holtz (1957)].
* After Meyerhof (1956). $\phi = 25 + 25D_r$ with more than 5 percent fines and $\phi = 30 + 25D_r$ with less than 5 percent fines. Use larger values for granular material with 5 percent or less fine sand and silt.
‡ It should be noted that excavated material or material dumped from a truck will weigh 70 to 90 pcf. Material must be quite dense and hard to weigh much over 130 pcf. Values of 105 to 115 pcf for nonsaturated soils are common.

Table Empirical values for q_u* and consistency of cohesive soils based on the standard penetration number

Consistency	Very soft	Soft	Medium	Stiff	Very stiff	Hard
q_u, ksf	0 — 0.5	1.0	2.0	4.0	8.0	
N, standard penetration resistance	0 — 2	4	8	16	32	
γ_{SAT} pcf (kN/m³)	100–120 (16–19)		110–130 (17–20)	120–140 (19–22)		

* These values should be used as a guide only. Local cohesive samples should be tested, and the relationship between N and the unconfined compressive strength q_u established as $q_u = KN$.

Choose a moist unit weight of 110 pcf, a saturated unit weight of 130 pcf, and a friction angle of 25 for the loose sand and gravel fill/alluvium

Choose a moist unit weight of 130 pcf, a saturated unit weight of 135 pcf, and a friction angle of 35 for the weathered/residual claystone

Drill rod	OD, in	Casing and core barrel	Core-barrel-bit OD, in	Approx. diam of borehole,* in	Diam of core sample, in
E	$1\frac{3}{16}$	EX	$1\frac{7}{16}$	$1\frac{1}{2}$	$\frac{7}{8}$
A	$1\frac{5}{8}$	AX	$1\frac{7}{8}$	2	$1\frac{1}{8}$
B	$1\frac{7}{8}$	BX†	$2\frac{3}{8}$	$2\frac{1}{2}$	$1\frac{5}{8}$
N	$2\frac{3}{8}$	NX	$1\frac{13}{16}$	3	$2\frac{1}{8}$

* Diameter of borehole is very nearly the ID of the casing.
† In soft or fractured rock, BX or larger cores are preferred.

$$RQD = \frac{\Sigma \text{ lengths of intact pieces of core} > 10 \text{ cm}}{\text{length of core advance}}$$

RQD	Rock Description	E_f/E_{lab}*
<0.25	very poor	0.15
0.25–0.50	poor	0.20
0.50–0.75	fair	0.25
0.75–0.90	good	0.3–0.7
>0.90	excellent	0.7–1.0

* Approximately for field laboratory compression strengths also.

Table C10.4.6.5-1—Summary of Elastic Moduli for Intact Rock (modified after Kulhawy, 1978)

Rock Type	No. of Values	No. of Rock Types	Elastic Modulus, E_R (ksi × 10^3)			Standard Deviation (ksi × 10^3)
			Maximum	Minimum	Mean	
Granite	26	26	14.5	0.93	7.64	3.55
Diorite	3	3	16.2	2.48	7.45	6.19
Gabbro	3	3	12.2	9.8	11.0	0.97
Diabase	7	7	15.1	10.0	12.8	1.78
Basalt	12	12	12.2	4.20	8.14	2.60
Quartzite	7	7	12.8	5.29	9.59	2.32
Marble	14	13	10.7	0.58	6.18	2.49
Gneiss	13	13	11.9	4.13	8.86	2.31
Slate	11	2	3.79	0.35	1.39	0.96
Schist	13	12	10.0	0.86	4.97	3.18
Phyllite	3	3	2.51	1.25	1.71	0.57
Sandstone	27	19	5.68	0.09	2.13	1.19
Siltstone	5	5	4.76	0.38	2.39	1.65
Shale	30	14	5.60	0.001	1.42	1.45
Limestone	30	30	13.0	0.65	5.7	3.73
Dolostone	17	16	11.4	0.83	4.22	3.44

Poisson's ratio for rock should be determined from tests on intact rock core.

Where tests on rock core are ratio may be estimated from Table

Choose E = 1,420 ksi = 1,420,000 psi for the intact Claystone based on an average value for Shale

Table C10.4.6.5-2—Summary of Poisson's Ratio for Intact Rock (modified after Kulhawy, 1978)

Rock Type	No. of Values	No. of Rock Types	Poisson's Ratio, ν			Standard Deviation
			Maximum	Minimum	Mean	
Granite	22	22	0.39	0.09	0.20	0.08
Gabbro	3	3	0.20	0.16	0.18	0.02
Diabase	6	6	0.38	0.20	0.29	0.06
Basalt	11	11	0.32	0.16	0.23	0.05
Quartzite	6	6	0.22	0.08	0.14	0.05
Marble	5	5	0.40	0.17	0.28	0.08
Gneiss	11	11	0.40	0.09	0.22	0.09
Schist	12	11	0.31	0.02	0.12	0.08
Sandstone	12	9	0.46	0.08	0.20	0.11
Siltstone	3	3	0.23	0.09	0.18	0.06
Shale	3	3	0.18	0.03	0.09	0.06
Limestone	19	19	0.33	0.12	0.23	0.06
Dolostone	5	5	0.35	0.14	0.29	0.08

© 2017 by the American Association of State Highway and Transportation Officials.
All rights reserved. Duplication is a violation of applicable law.

Hoek and Bray, Rock Slope Engineering, 1974

TABLE 1 - TYPICAL SOIL AND ROCK PROPERTIES

Description			Unit weight (Saturated/dry)		Friction angle	Cohesion	
Type		Material	lb/ft³	kN/m³	degrees	lb/ft²	kPa
Cohesionless	Sand	Loose sand, uniform grain size	118/90	19/14	28-34*		
		Dense sand, uniform grain size	130/109	21/17	32-40*		
		Loose sand, mixed grain size	124/99	20/16	34-40*		
		Dense sand, mixed grain size	135/116	21/18	38-46*		
	Gravel	Gravel, uniform grain size	140/130	22/20	34-37*		
		Sand and gravel, mixed grain size	120/110	19/17	48-45*		
	Blasted/broken rock	Basalt	140/110	22/17	40-50*		
		Chalk	80/62	13/10	30-40*		
		Granite	125/110	20/17	45-50*		
		Limestone	120/100	19/16	35-40*		
		Sandstone	110/80	17/13	35-45*		
		Shale	125/100	20/16	30-35*		
Cohesive	Clay	Soft bentonite	80/30	13/6	7-13	200-400	10-20
		Very soft organic clay	90/40	14/6	12-16	200-600	10-30
		Soft, slightly organic clay	100/60	16/10	22-27	400-1000	20-50
		Soft glacial clay	110/76	17/12	27-32	600-1500	30-70
		Stiff glacial clay	130/105	20/17	30-32	1500-3000	70-150
		Glacial till, mixed grain size	145/130	23/20	32-35	3000-5000	150-250
	Rock	Hard igneous rocks - granite, basalt, porphyry	160 to 190**	25 to 30	35-45	720000-1150000	35000-55000
		Metamorphic rocks - quartzite, gneiss, slate	160 to 180	25 to 28	30-40	400000-800000	20000-40000
		Hard sedimentary rocks - limestone, dolomite, sandstone	150 to 180	23 to 28	35-45	200000-600000	10000-30000
		Soft sedimentary rock - sandstone, coal, chalk, shale	110 to 150	17 to 23	25-35	20000 - 400000	1000-20000

* Higher friction angles in cohesionless materials occur at low confining or normal stresses as discussed in Chapter 5.

** For intact rock, the unit weight of the material does not vary significantly between saturated and dry states with the exception of materials such as porous sandstones.

Choose a moist unit weight of 140 pcf and a saturated unit weight of 140 pcf for intact Claystone

SPECIFICATIONS COMMENTARY

Table 10.6.3.2.2-2 – Typical Range of Uniaxial Compressive Strength (Co) as a Function of Rock Category and Rock Type

ROCK CATEGORY	GENERAL DESCRIPTION	ROCK TYPE	Co[1] ksf
A	Carbonate rocks with well-developed crystal cleavage	Dolostone	600 - 6,400
		Limestone	600 - 6,000
		Carbonatite	800 - 1,400
		Marble	800 - 5,000
		Tactite-Skarn	2,800 - 6,800
B	Lithifield argillaceous rock	Argillite	600 - 3,000
		Claystone	30 - 170
		Marlstone	1,000 - 4,000
		Phyllite	600 - 5,000
		Siltstone	200 - 2,400
		Shale[2]	150 - 740
		Slate	3,000 - 4,400
C	Arenaceous rocks with strong crystals and poor cleavage	Conglomerate	600 - 4,600
		Sandstone	1,400 - 3,600
		Quartzite	1,200 - 8,000
D	Fine-grained igneous crystalline rock	Andesite	2,000 - 3,800
		Diabase	450 - 12,000
E	Coarse-grained igneous and metamorphic crystalline rock	Amphibolite	2,400 - 5,800
		Gabbro	2,600 - 6,400
		Gneiss	500 - 6,400
		Granite	300 - 6,800
		Quartzdiorite	200 - 2,000
		Quartzmonzonite	2,800 - 3,400
		Schist	200 - 3,000
		Syenite	3,800 - 9,000

Choose 30 ksf = 200 psi for intact Claystone based on the low end of the typical value range

[1] Range of Uniaxial Compressive Strength values reported by various investigations

[2] Not including oil shale

10.6.3.2.3 Analytic Method

The following shall replace A10.6.3.2.3.

The nominal bearing resistance of foundations on rock shall be determined using established rock mechanics principles based on the rock mass strength parameters determined in accordance with D10.4.6.4. The influence of discontinuities on the failure mode shall also be considered.

LPILE v2019 Technical Manual

up to the point where the computed soil resistance was equal to about one-half of the ultimate bearing stress.

In terms of *p-y* curves, Terzaghi recommended a series of straight lines with slopes that increase linearly with depth, as indicated in Equation 3-46.

$$E_s = k\,x \quad \text{..... (3-46)}$$

where k is a constant giving the variation of soil modulus with depth, and x is the depth below ground surface. Terzaghi's recommended values for k values in both US customary units and SI units are presented in Table 3-5.

The k values recommended by Terzaghi in Table 3-5 are now known to be too conservative. Users of LPile are advised to use the values recommended by Reese and Matlock presented later in this manual because those values are based on load tests of fully instrumented piles and are supported by high quality soil investigations. Terzaghi's recommended values were based on a literature review conducted in the early 1950's, not a direct evaluation of pile load testing results, and should be recognized as being preliminary recommendations. Terzaghi later acknowledged around 1958 that he had some doubts about the source data and he ceased recommending use of the values shown in Table 3-5.

3.4.1.2 Analytical Solutions for Ultimate Resistance

Two models are used for computing the ultimate resistance for piles in sand. These models follow a procedure similar to that used for clay. The first of the models for the soil resistance near the ground surface is shown in **Figure 3.25**. The total lateral force F_{pt} (**Figure 3.25**(c)) may be computed by subtracting the active force F_a, computed by use of Rankine theory, from the passive force F_p, computed for the model by assuming that the Mohr-Coulomb failure condition is satisfied on vertical wedge side planes defined by *ADE* and *BCF*, and on the sloping wedge surface defined by *AEFB* in **Figure 3.25**(a). The directions of the resultant forces are shown in **Figure 3.25**(b). Solutions other than the ones shown here have been developed by assuming a friction force on the pile-soil interface surface defined by *DEFC* (assumed to be zero in the analysis shown here) and by assuming the water table to be within the wedge (the unit weight is assumed to be constant in the analysis shown here).

Table 3-5 *k* Values Recommended by Terzaghi for Laterally Loaded Piles in Sand

Relative Density	*k*, MN/m³ (pci)	
	Dry or Moist Sand	Submerged Sand
Loose	0.95 - 2.8 (3.5 - 10.4)	0.53 - 1.7 (2.1 - 6.4)
Medium	3.5 - 10.9 (13.0 - 40.0)	2.2 - 7.3 (8.0 - 27.0)
Dense	13.8 - 27.7 (51.0 - 102.0)	8.3 - 17.9 (32.0 - 64.0)

* Per guidance above, K values from Table 3-5. See attached Tables 3-6 + 3-7 for selected K values

LPILE v2019 Technical Manual

Table 3-6 Representative Values of *k* for Fine Sand Below the Water Table for Static and Cyclic Loading

Recommended *k*	Relative Density		
	Loose	Medium	Dense
MN/m^3 (pci)	5.4 (20.0)	16.3 (60.0)	34 (125.0)

* Choose K = 20 pci for Fill/Alluv below GWT and K = 25pc for Fill/Alluv above GWT. Choose K = 125 pci for residual claystone below GWT

Table 3-7 Representative Values of *k* for Fine Sand Above Water Table for Static and Cyclic Loading

Recommended *k*	Relative Density		
	Loose	Medium	Dense
MN/m^3 (pci)	6.8 (25.0)	24.4 (90.0)	61.0 (225.0)

If the sand profile is coarse or well-graded sand, the user may consider using a higher value of *k* that those suggested in the tables above. While experimental data for *k* in well-graded sands is poorly documented, use of values 10 to 50 percent higher may be appropriate in dense and very dense well-graded sands that do not contain any compressible minerals such as mica.

7. Fit the parabola between point *k* and point *m* as follows:

   a. Compute the slope of the *p-y* curve between point *m* and point *u* using

$$m = \frac{p_u - p_m}{y_u - y_m} \quad \text{(3-62)}$$

   b. Compute the power of the parabolic section using

$$n = \frac{p_m}{m y_m} \quad \text{(3-63)}$$

   c. Compute the coefficient $\overline{C}$ using

$$\overline{C} = \frac{p_m}{y_m^{1/n}} \quad \text{(3-64)}$$

8. Compute the *y* value defining point *k* using

$$y_k = \left(\frac{\overline{C}}{kx}\right)^{\frac{n}{n-1}} \quad \text{(3-65)}$$

Compute the *p* value defining point *k* using

LPILE v2019 User's Manual

Undrained Shear Strength: Values of undrained shear strength (c_u) for clays and silts at each depth are entered in standard units of force per unit area. The undrained shear strength is not needed for sand layers. The undrained shear strength is generally taken as half of the unconfined compressive strengths.

Internal Friction (degrees): Values of the angle of internal friction ϕ for sands and/or silts at each soil depth are entered in degrees.

Strain Factor E50: Values of ε_{50} strain at 50% of the maximum stress. The strain factor ε_{50} for clays and/or silts at each soil depth are entered in dimensionless units of strain.

If soil test data are available, the user may enter the value based on the stress-strain curves measured in the soil laboratory. The *p-y* curves for weak rocks need a strain parameter k_{rm} which is analogous to ε_{50}. More information regarding k_{rm} and ε_{50} can be found in the *Technical Manual.*

Initial Mass Modulus for Weak Rock: The initial mass modulus for weak rock should be entered for this value. This value may be measured in the field using an appropriate test or may be obtained from the product of the modulus reduction ratio and Young's modulus measured on intact rock specimens in the laboratory

Uniaxial Compressive Strength: This value is the uniaxial compressive strength of weak rock at the specified depth. Values at elevations between the top and bottom elevations will be determined by linear interpolation.

Any input values that are considered unreasonable are flagged in the output file and a warning dialog box is displayed. However, the analysis is performed normally.

Rock Quality Designation: The secondary structure of the weak rock is described using the Rock Quality Designation (*RQD*). Enter the value of *RQD* in percent for the weak rock.

Strain Factor k_{rm}: The parameter k_{rm} for weak rock typically ranges between 0.0005 and 0.00005. The input dialog for weak rock is shown in Figure 3.36 as an example.

* Choose Krm= 0.00005 for Intact Claystone

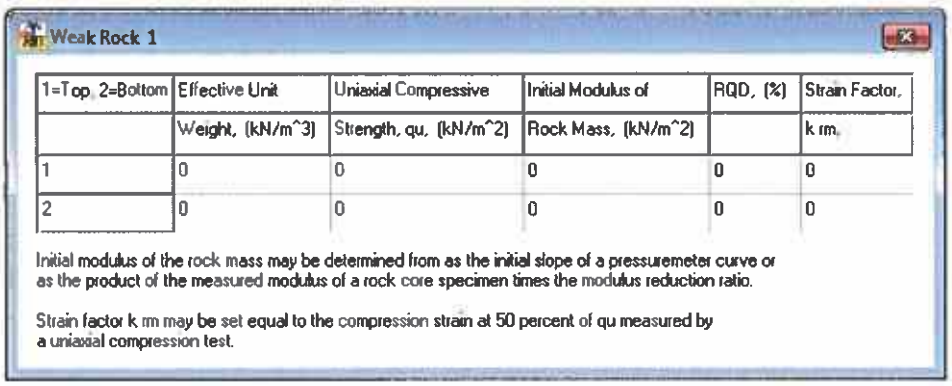


Figure 3.36 Dialog for Properties of Weak Rock

The input for massive rock requires strength parameters defined using the Hoek-Brown strength criterion. In addition to effective unit weight and uniaxial compressive strength, these parameters include:

Hoek-Brown Material index, m_i, is a dimensionless number ranging from 4 to 32 that depends on the type of rock.