GZA
GeoEnvironmental, Inc.

Engineers and Scientists

March 31, 2014
File No. 02.0171926.00-C, PC

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Mr. Charlie Ezequelle
Renaud Bros., Inc.
283 Fort Bridgeman Road #2
Vernon, Vermont 05661

Re: Wave Equation Analyses
Guilford BRO 1442 (36)
Guilford, Vermont

Dear Mr. Ezequelle:

At your request, GZA GeoEnvironmental, Inc. (GZA) has a performed Wave Equation Analyses of Piles (WEAP) for the hammer-pile-soil system proposed on the above referenced project. These analyses were performed in general accordance with the project specifications. A copy of the completed GRLWEAP outputs are attached and the WEAP inputs are summarized below:

- Hammer- The APE D19-42 single acting diesel hammer with a ram weight of 4,189 lbs. and a maximum rated stroke of 11.3 feet, yielding a maximum rated energy of 47,335 ft-lbs. The hammer cushioning material reportedly consists of 2 inches of Monocast MC-904(P) blue nylon. No pile cushion material is required for the pile type detailed below.

- Pile - 30-foot and 40-foot long, HP 14x89 Grade 50 steel piles are modeled at the East and West Abutments, respectively. The cross-sectional area for this pile type is 26.1 square inches. The specified nominal axial resistance of 323 kips is based upon dividing the maximum factored axial pile load of 210 kips by a performance factor of 0.65. The maximum allowable driving stresses for Grade 50 steel is 45 ksi (i.e. $0.9f_y$).

- Soil - Based on the subsurface information provided and the anticipated driving conditions, the a unique resistance profile is modeled at each abutment.

  East Abutment

  The pile resistance profile for the East Abutment is modeled as 50% end-bearing and 50% skin friction, with a 10-foot long rectangular distribution in the silt stratum overlaying a larger rectangular distribution in the completely weathered bedrock along the lower 10 feet of the pile.

  West Abutment

  The pile resistance profile for the West Abutment is modeled as 50% end-bearing and 50% skin friction, with a 20-foot long triangular distribution in the sand stratum

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overlaying a rectangular distribution in the hard silts along the lower 10 feet of the pile.

- Analysis Two analyses model the above hammer-pile-soil system:

  1. Variable capacity analysis which develops a driving resistance based on the most efficient hammer stroke.

  2. Constant capacity analysis (i.e., Inspector's Chart) which develops a driving resistance based on a varied hammer stroke.

- Results The results of these analyses are tabulated below:

Nominal Pile Resistance: 323 kips

Pile Hammer	Substructure	Blow Count (bpi)	Ram Stroke (ft)	Compressive Stress (ksi)	Transfer Energy (kip-ft)
APE D19-42	East Abutment	3 bpi	8.1 ft.	25.9 ksi	20.7 kip-ft
	West Abutment	3 bpi	8.1 ft.	25.9 ksi	20.7 kip-ft

The results tabulated above indicate that the APE D19-42 open-end diesel hammer can drive the specified HP14x89 Grade 50 steel piles to a nominal resistance of 323 kips without overstressing the pile section. Based on the above results, the preliminary recommended driving resistance is 3 blows per inch with the APE D19-42 providing a ram stroke of approximately 8.0 feet. The maximum estimated driving stress of 25.9 ksi is within the allowable limits for Grade 50 steel. We recommend that this driving criterion be developed for a minimum of 3 consecutive inches. It is our understanding the driving criterion will be verified with the specified dynamic pile-testing program. The specified dynamic pile testing will be performed to monitor the driving stresses, verify the above results and determine the final driving criterion for the production piles. Note that the driving criterion may be refined based on the results of the dynamic pile test program.

Please note that the project documents state that the specified HP14x89 steel piles are to achieve a minimum of 25 feet penetration below the bottom of the pile cap and be driven to refusal in bedrock. The borings indicate very poor quality bedrock (i.e. completely weathered or highly fractured) overlaying fair quality bedrock. We recommend that piles be installed to the required nominal resistance of 323 kips as determined by dynamic pile testing methods and then dynamically monitored during restrike to evaluate the time-dependent pile capacity.

If the pile driving system should demonstrate refusal conditions (i.e., sudden increase in ram stroke and penetration resistance), we recommend a refusal criteria of 10 blows per half-inch of pile penetration with the APE D19-42 providing a minimum 8.0 foot ram stroke.

If you have any questions or require additional information, please contact the undersigned.

Very truly yours,

GZA GEOENVIRONMENTAL, INC.

Michael J. Deery
Project Engineer

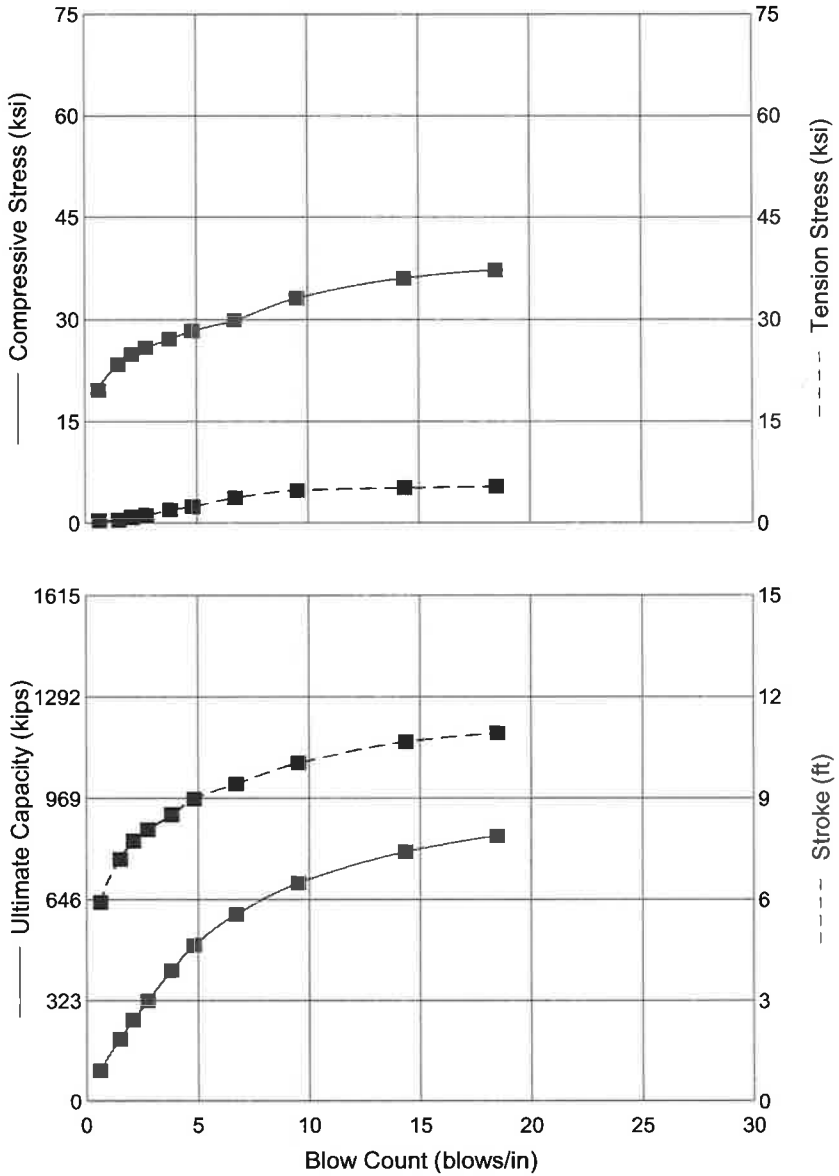
Bradford W. Roberts
Consultant / Reviewer

John E. Regan
Principal

Attachments: Wave Equation Analysis Results

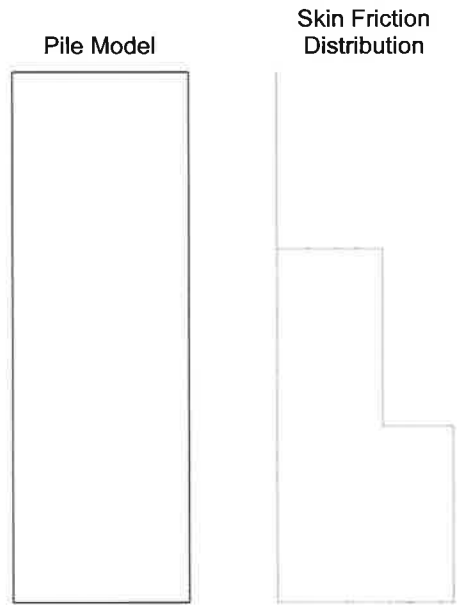
GZA GeoEnvironmental Inc.
BRO 1442(36) APE D19-42 30'HP14x89 vc

31-Mar-2014
GRLWEAP Version 2010



APE D 19-42

Ram Weight	4.19	kips
Efficiency	0.800	
Pressure	1710 (100%)	psi
Helmet Weight	3.00	kips
Hammer Cushion	34825	kips/in
COR of H.C.	0.920	
Skin Quake	0.100	in
Toe Quake	0.100	in
Skin Damping	0.050	sec/ft
Toe Damping	0.150	sec/ft
Pile Length	30.00	ft
Pile Penetration	25.00	ft
Pile Top Area	26.10	in2



Res. Shaft = 50 %
(Proportional)

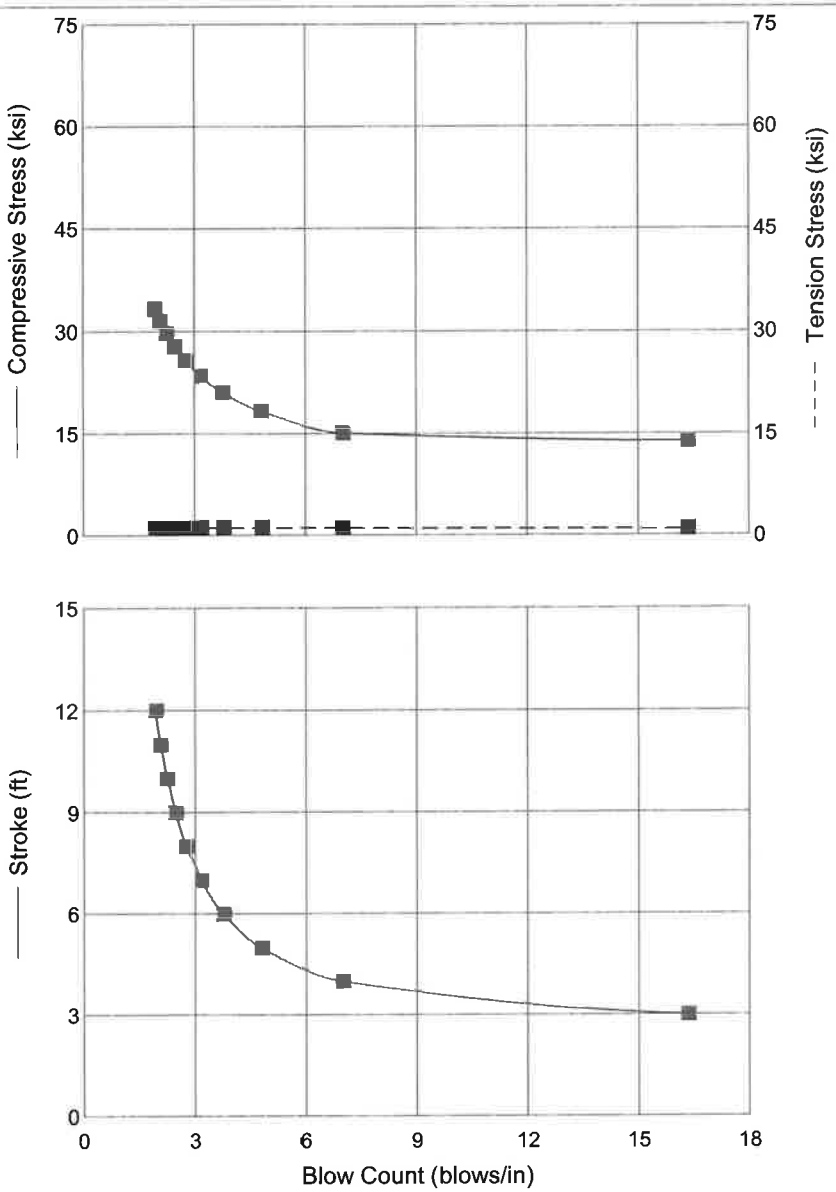
GZA GeoEnvironmental Inc.
BRO 1442(36) APE D19-42 30'HP14x89 vc

31-Mar-2014
GRLWEAP Version 2010

Ultimate Capacity kips	Maximum Compression Stress ksi	Maximum Tension Stress ksi	Blow Count blows/in	Stroke ft	Energy kips-ft
100.0	19.58	0.41	0.6	5.92	23.29
200.0	23.35	0.45	1.5	7.19	21.27
262.0	24.86	0.86	2.1	7.74	20.99
323.0	25.85	1.16	2.8	8.08	20.74
420.0	27.14	1.95	3.8	8.52	20.81
500.0	28.34	2.43	4.8	8.98	21.36
600.0	29.91	3.75	6.7	9.43	21.88
700.0	33.18	4.86	9.5	10.05	23.01
800.0	36.09	5.22	14.4	10.67	24.56
850.0	37.27	5.39	18.5	10.92	25.11

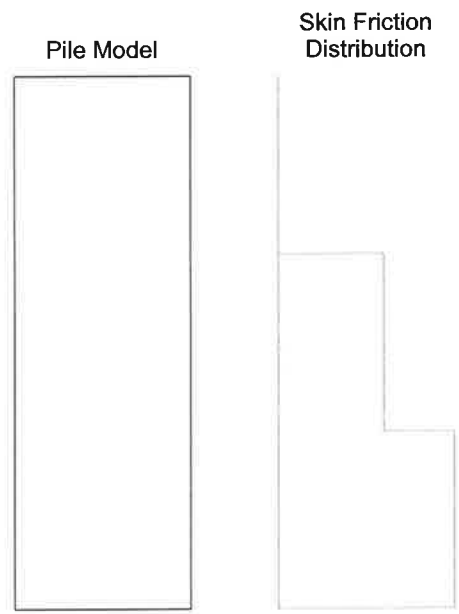
GZA GeoEnvironmental Inc.
BRO 1442(36) APE D19-42 30'HP14x89 cc

28-Mar-2014
GRLWEAP Version 2010



APE D 19-42

Capacity	323.0	kips
Ram Weight	4.19	kips
Efficiency	0.800	
Pressure	1710 (100%)	psi
Helmet Weight	3.00	kips
Hammer Cushion	34825	kips/in
COR of H.C.	0.920	
Skin Quake	0.100	in
Toe Quake	0.100	in
Skin Damping	0.050	sec/ft
Toe Damping	0.150	sec/ft
Pile Length	30.00	ft
Pile Penetration	25.00	ft
Pile Top Area	26.10	in2



Res. Shaft = 50 %
(Proportional)

GZA GeoEnvironmental Inc. 28-Mar-2014
BRO 1442(36) APE D19-42 30'HP14x89 cc GRLWEAP Version 2010

Ultimate Capacity kips	Maximum Compression Stress ksi	Maximum Tension Stress ksi	Blow Count blows/in	Stroke ft	Energy kips-ft
323.0	13.80	0.98	16.4	3.00	5.04
323.0	15.07	1.12	7.0	4.00	8.34
323.0	18.24	1.22	4.8	5.00	11.48
323.0	21.00	1.23	3.8	6.00	14.57
323.0	23.46	1.20	3.2	7.00	17.54
323.0	25.68	1.15	2.8	8.00	20.47
323.0	27.73	1.12	2.5	9.00	23.39
323.0	29.69	1.09	2.3	10.00	26.33
323.0	31.47	1.11	2.1	11.00	29.17
323.0	33.19	1.17	2.0	12.00	32.05

GZA GeoEnvironmental Inc.
BRO 1442(36) APE D19-42 40'HP14x89 vc

31-Mar-2014
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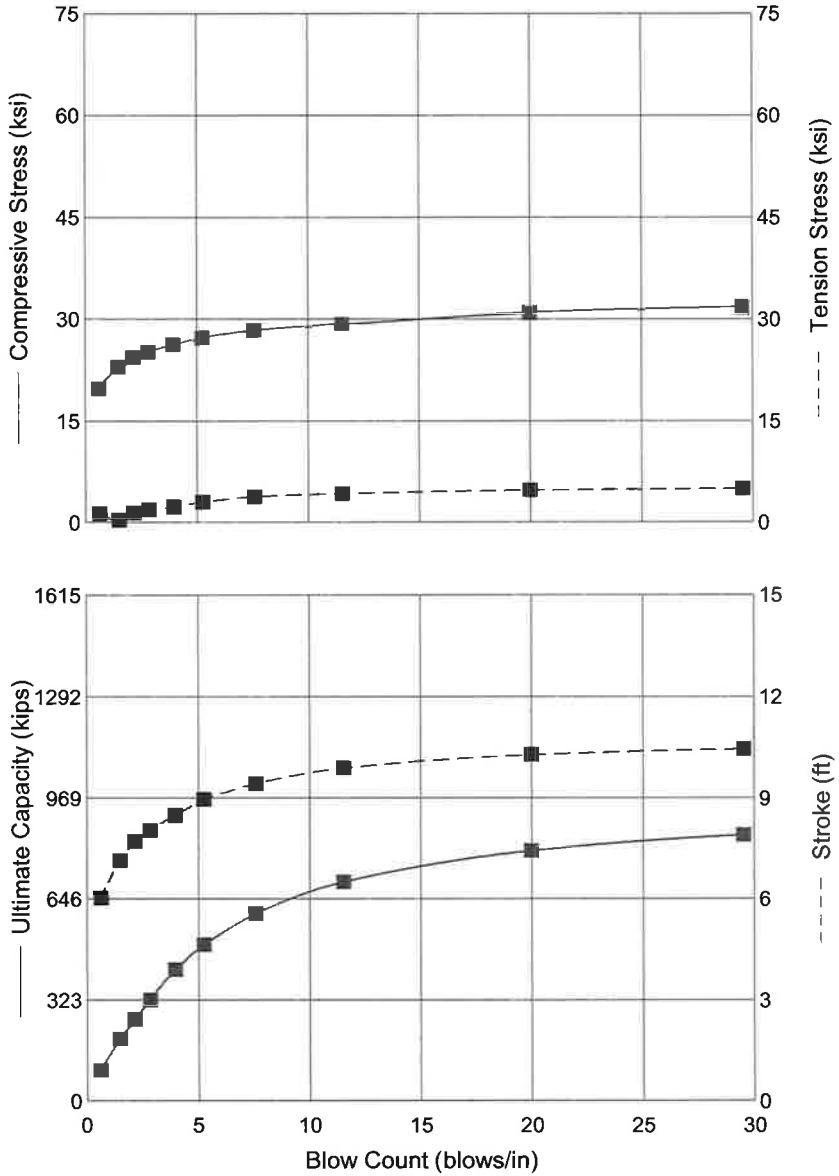

APE D 19-42

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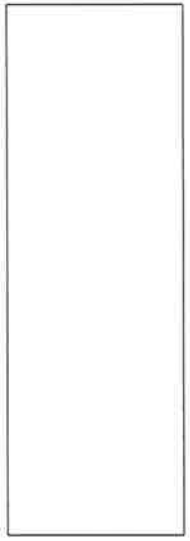
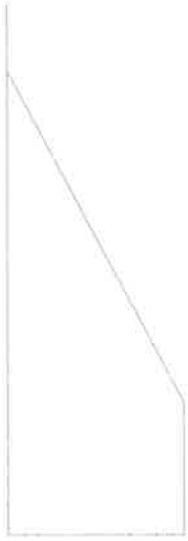
Helmet Weight	3.00	kips
Hammer Cushion	34825	kips/in
COR of H.C.	0.920	
Skin Quake	0.100	in
Toe Quake	0.100	in
Skin Damping	0.050	sec/ft
Toe Damping	0.150	sec/ft
Pile Length	40.00	ft
Pile Penetration	35.00	ft
Pile Top Area	26.10	in2

Pile Model



Skin Friction Distribution



Res. Shaft = 50 %
(Proportional)

GZA GeoEnvironmental Inc.
BRO 1442(36) APE D19-42 40'HP14x89 vc

31-Mar-2014
GRLWEAP Version 2010

Ultimate Capacity kips	Maximum Compression Stress ksi	Maximum Tension Stress ksi	Blow Count blows/in	Stroke ft	Energy kips-ft
100.0	19.68	1.29	0.6	6.03	23.10
200.0	22.84	0.37	1.5	7.16	21.19
262.0	24.23	1.41	2.2	7.73	21.04
323.0	25.05	1.84	2.9	8.05	20.99
420.0	26.14	2.28	4.0	8.50	21.31
500.0	27.18	2.99	5.3	8.96	22.07
600.0	28.21	3.76	7.6	9.44	22.97
700.0	29.20	4.22	11.5	9.90	24.04
800.0	30.90	4.72	20.0	10.29	24.99
850.0	31.71	4.97	29.5	10.46	25.30

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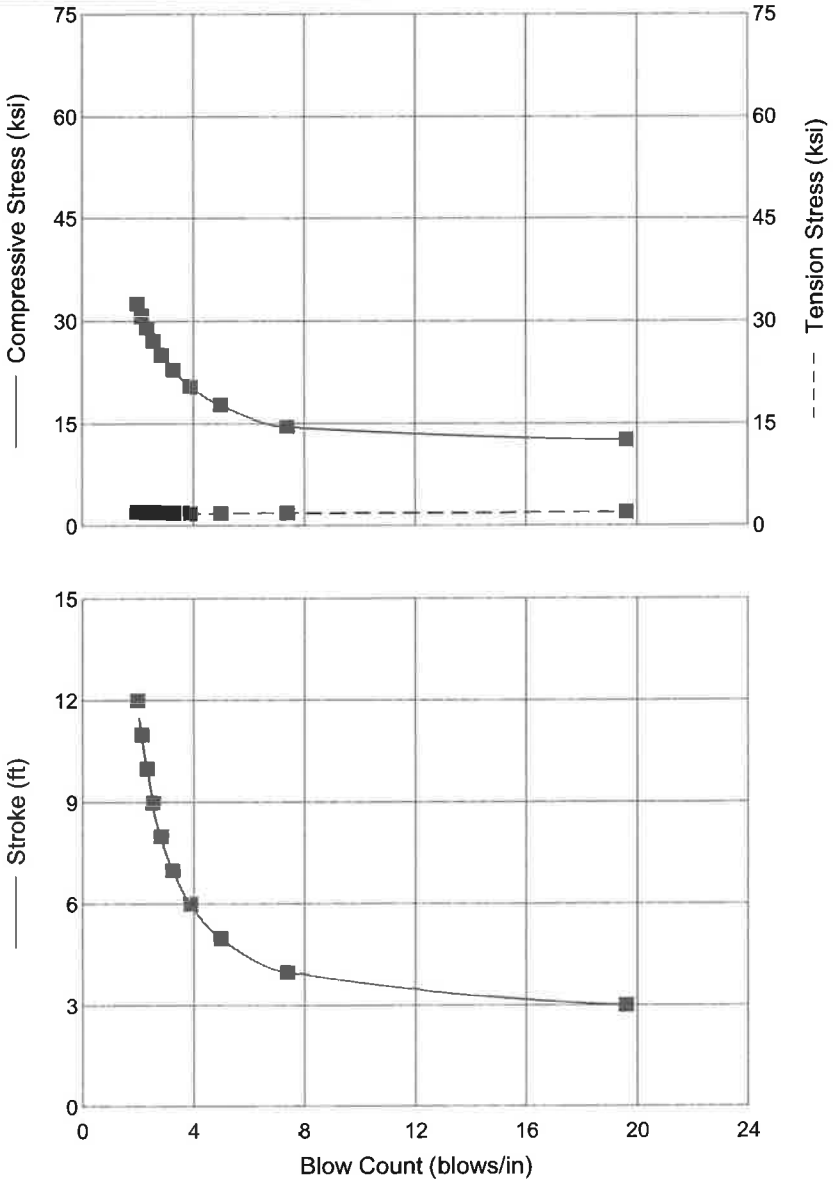

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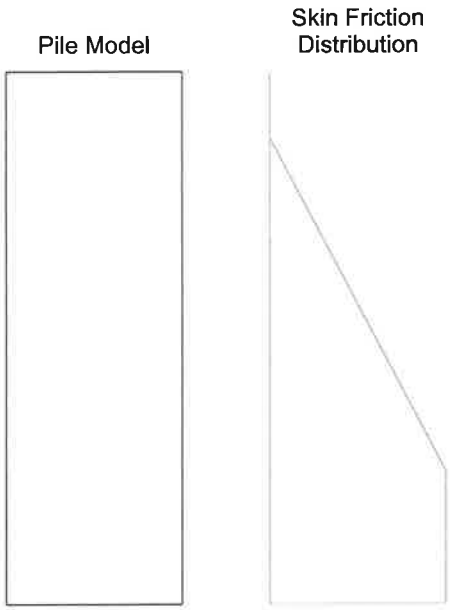

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Ultimate Capacity kips	Maximum Compression Stress ksi	Maximum Tension Stress ksi	Blow Count blows/in	Stroke ft	Energy kips-ft
323.0	12.59	1.97	19.6	3.00	5.35
323.0	14.51	1.86	7.4	4.00	8.68
323.0	17.62	1.79	5.0	5.00	11.82
323.0	20.34	1.80	3.9	6.00	14.91
323.0	22.74	1.81	3.3	7.00	17.89
323.0	24.94	1.84	2.9	8.00	20.83
323.0	26.97	1.88	2.6	9.00	23.77
323.0	28.88	1.90	2.3	10.00	26.64
323.0	30.68	1.92	2.1	11.00	29.53
323.0	32.41	1.94	2.0	12.00	32.40