GZA
GeoEnvironmental, Inc.

Engineers and Scientists

November 3, 2014
File No. 02.0172124.00-C, PC

Mr. Chad Contaldi
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Re: Wave Equation Analyses
Rockingham BRF 0126(12)
Rockingham, Vermont

Dear Mr. Contaldi:

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. Copies 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 11.25 feet, yielding a maximum rated energy of 47,126 foot-lbs. The D19-42 is equipped with a ratchet style fuel pump with four settings. The fuel pump settings are designed to limit the ram stroke to 5.6 feet, 7.4 feet, 9.3 feet, and 11.25 feet (open) yielding rated energies of 23,566 foot-lbs., 31,107 foot-lbs., 39,119 foot-lbs., and 47,126 ft-lbs., respectively. Note the HP10x57 piles are modeled with the APE D19-42 operating on fuel setting 1 (i.e. rated 5.6 foot ram stroke) to produce a reasonable driving criterion. 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 - 40-foot long, HP 10x57 Grade 50 steel piles are modeled. The cross-sectional area for this pile type is 16.7 square inches. The specified ultimate resistance is 265 kips. 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, a frictional resistance profile and an end bearing soil resistance profile is modelled.

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Frictional Profile

The frictional resistance profile is modeled as 50% end-bearing and 50% skin friction triangularly distributed along the lower 30 feet of the pile length.

End Bearing Profile

The end bearing resistance profile is modeled as 90% end-bearing and 10% skin friction triangularly distributed along the lower 30 feet of the pile length.

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

  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:

Ultimate Pile Resistance: 265 kips

Pile Hammer	Fuel Setting	Resistance Profile	Blow Count (bpi)	Ram Stroke (ft)	Compressive Stress (ksi)	Transfer Energy (kip-ft)
APE D19-42	1	Friction	4 bpi	5.8 ft.	22.6 ksi	14.0 kip-ft
		End Bearing	4 bpi	6.0 ft.	29.0 ksi	14.4 kip-ft

The results tabulated above indicate that the APE D19-42 open-end diesel hammer can drive the modeled HP10x57 Grade 50 steel piles to the specified nominal resistance of 265 kips without overstressing the pile section. Based on the above results, the preliminary recommended driving resistance is 4 blows per inch with the APE D19-42 operating on fuel setting 1 and providing a ram stroke of approximately 6.0 feet. The maximum estimated driving stress of 29.0 ksi is within the allowable limits for Grade 50 steel. We recommend that this driving criterion be developed for a minimum of six (6) consecutive inches.

DISCUSSION

The project documents imply that the specified HP10x57 steel piles are to develop the required nominal resistance in the overburden at an estimated pile tip elevation of+367.0 (i.e. approximately 80 feet below the specified bottom of slab elevation). The contract boring logs indicates very dense sands approximately 20 feet (i.e. at approximate elevation +423.0) below the proposed bottom of each abutment slab. Based on review of the contract boring logs, the Contractor estimates a 20-foot pile embedment into the

underlying very dense sands will provide the specified nominal resistance. This assessment will be confirmed with the specified dynamic pile test program.

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

Very truly yours,

GZA GEOENVIRONMENTAL, INC.

(for) Michael J. Deery
Project Engineer

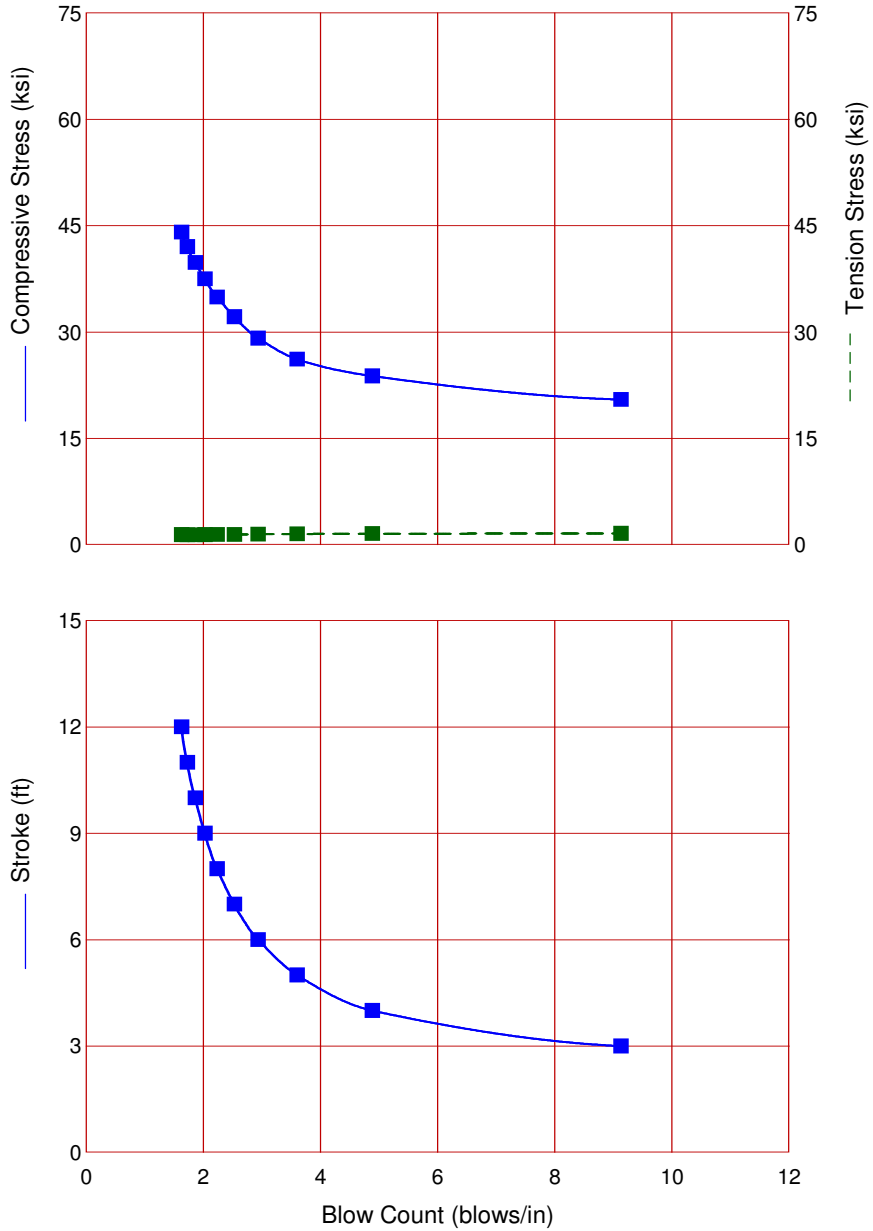
Bradford W. Roberts
Consultant / Reviewer

John E. Regan
Principal

Attachments: Wave Equation Analysis Results

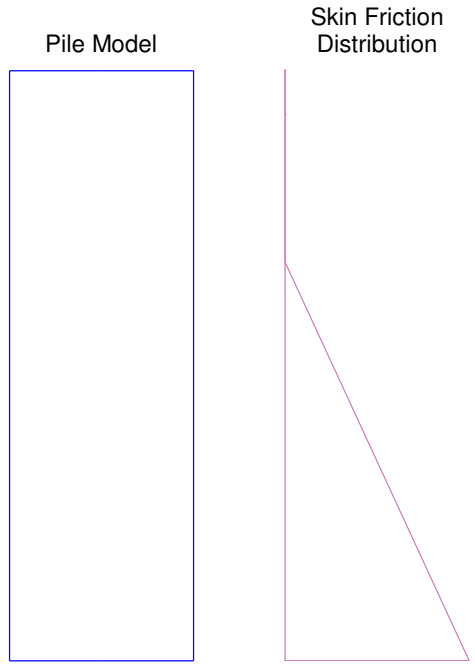
GZA GeoEnvironmental Inc.
BRF 0126(12) APE D19 40'HP10x57 VC EB

27-Oct-2014
GRLWEAP Version 2010



APE D 19-42

Capacity	265.0	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	40.00	ft
Pile Penetration	37.00	ft
Pile Top Area	16.70	in2



Res. Shaft = 10 %
(Proportional)

GZA GeoEnvironmental Inc. 27-Oct-2014
BRF 0126(12) APE D19 40'HP10x57 VC EB GRLWEAP Version 2010

Ultimate Capacity kips	Maximum Compression Stress ksi	Maximum Tension Stress ksi	Blow Count blows/in	Stroke ft	Energy kips-ft
265.0	20.48	1.60	9.1	3.00	6.93
265.0	23.81	1.56	4.9	4.00	10.52
265.0	26.16	1.52	3.6	5.00	13.72
265.0	29.14	1.49	2.9	6.00	16.84
265.0	32.16	1.46	2.5	7.00	19.84
265.0	34.93	1.44	2.2	8.00	22.83
265.0	37.47	1.41	2.0	9.00	25.73
265.0	39.79	1.40	1.9	10.00	28.60
265.0	42.04	1.41	1.7	11.00	31.49
265.0	44.08	1.42	1.6	12.00	34.26

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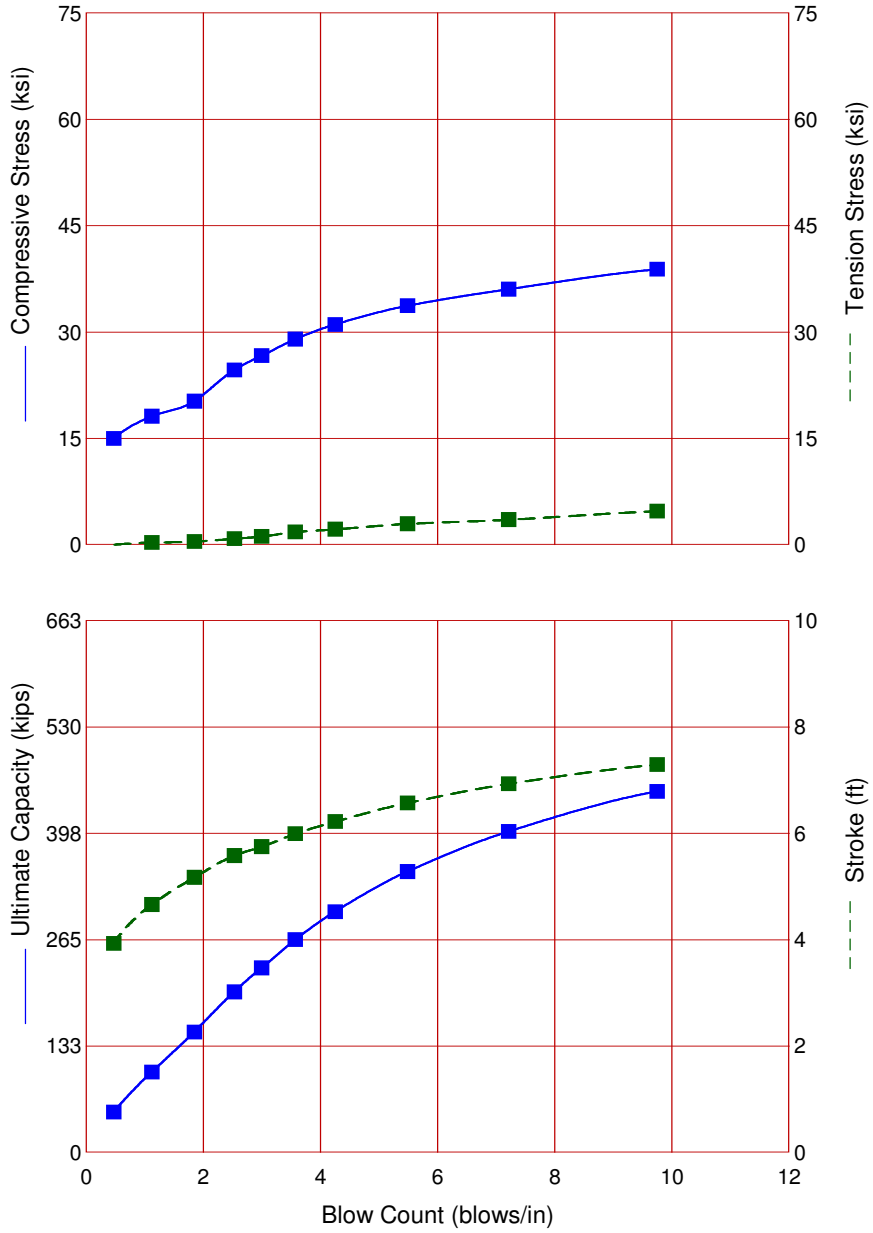

APE D 19-42

Ram Weight	4.19	kips
Efficiency	0.800	
Pressure	1247 (73%)	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	40.00	ft
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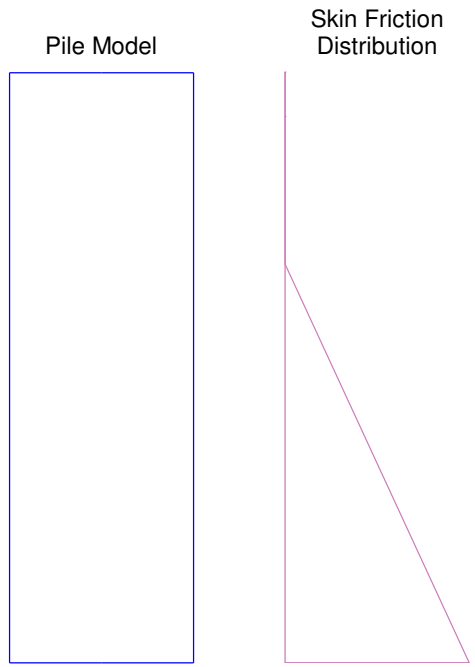

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Ultimate Capacity kips	Maximum Compression Stress ksi	Maximum Tension Stress ksi	Blow Count blows/in	Stroke ft	Energy kips-ft
50.0	14.99	0.00	0.5	3.93	16.23
100.0	18.12	0.32	1.1	4.66	14.17
150.0	20.24	0.44	1.8	5.17	13.68
200.0	24.62	0.85	2.5	5.58	13.89
230.0	26.66	1.17	3.0	5.75	14.02
265.0	28.99	1.80	3.6	5.99	14.40
300.0	31.06	2.17	4.3	6.22	14.84
350.0	33.69	2.95	5.5	6.57	15.51
400.0	36.03	3.53	7.2	6.93	16.21
450.0	38.84	4.72	9.8	7.29	16.97

GZA GeoEnvironmental Inc.
BRF 0126(12) APE D19 40'HP10x57 VC FR

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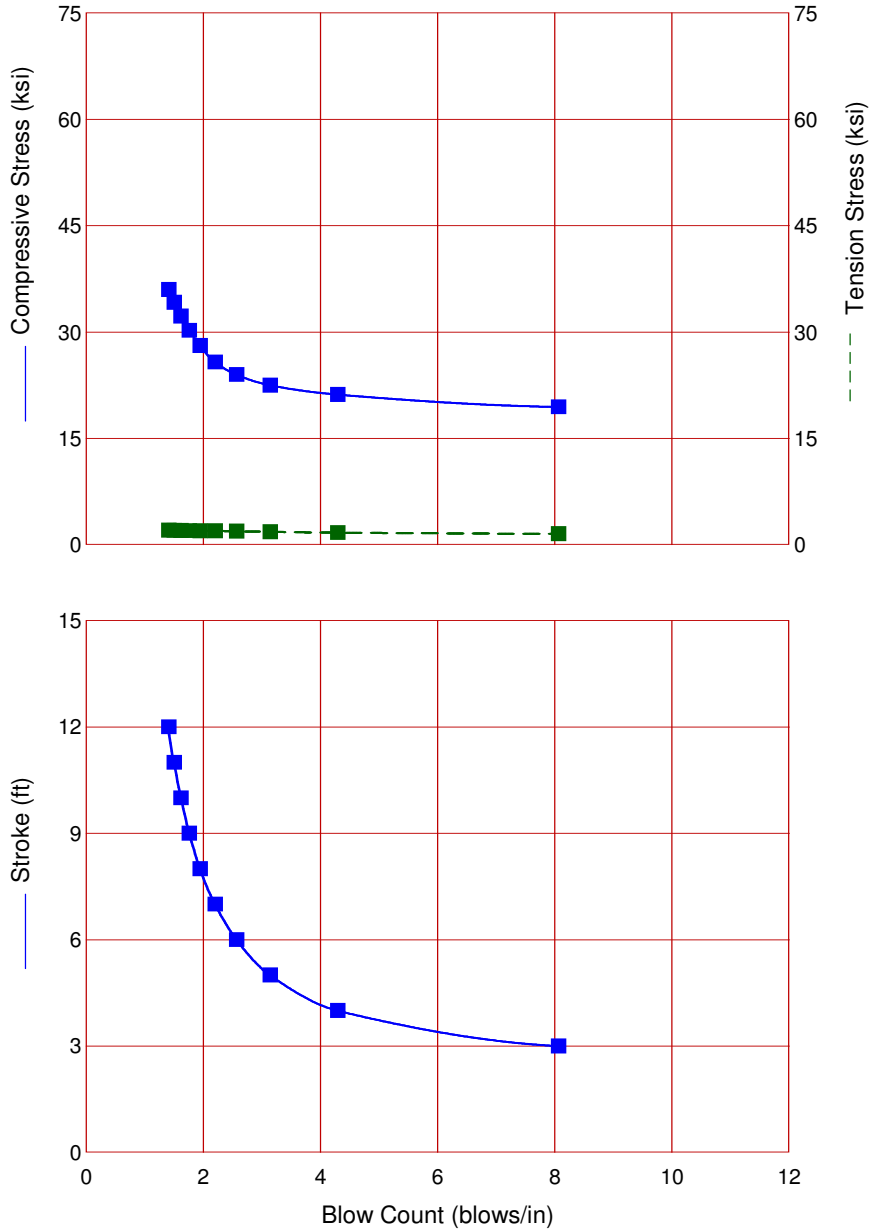
GRLWEAP Version 2010



APE D 19-42

Capacity	265.0	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	40.00	ft
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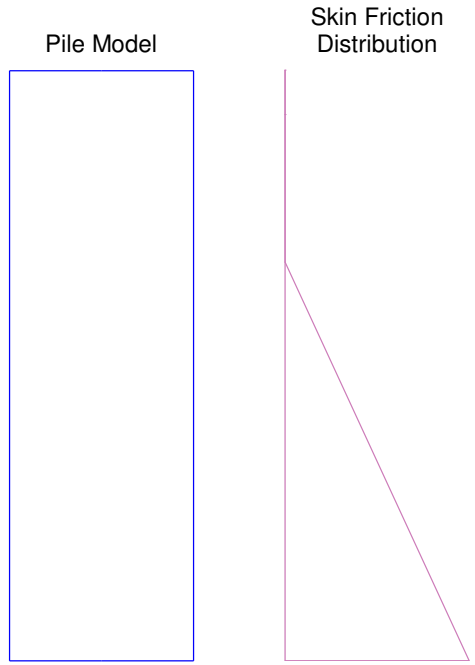

Res. Shaft = 50 %
(Proportional)

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Ultimate Capacity kips	Maximum Compression Stress ksi	Maximum Tension Stress ksi	Blow Count blows/in	Stroke ft	Energy kips-ft
265.0	19.43	1.55	8.1	3.00	6.79
265.0	21.19	1.72	4.3	4.00	10.45
265.0	22.49	1.83	3.1	5.00	13.81
265.0	24.01	1.91	2.6	6.00	16.96
265.0	25.75	1.95	2.2	7.00	20.09
265.0	28.09	1.97	1.9	8.00	23.16
265.0	30.24	1.99	1.8	9.00	26.14
265.0	32.26	2.01	1.6	10.00	29.05
265.0	34.20	2.02	1.5	11.00	31.99
265.0	35.98	2.05	1.4	12.00	34.79

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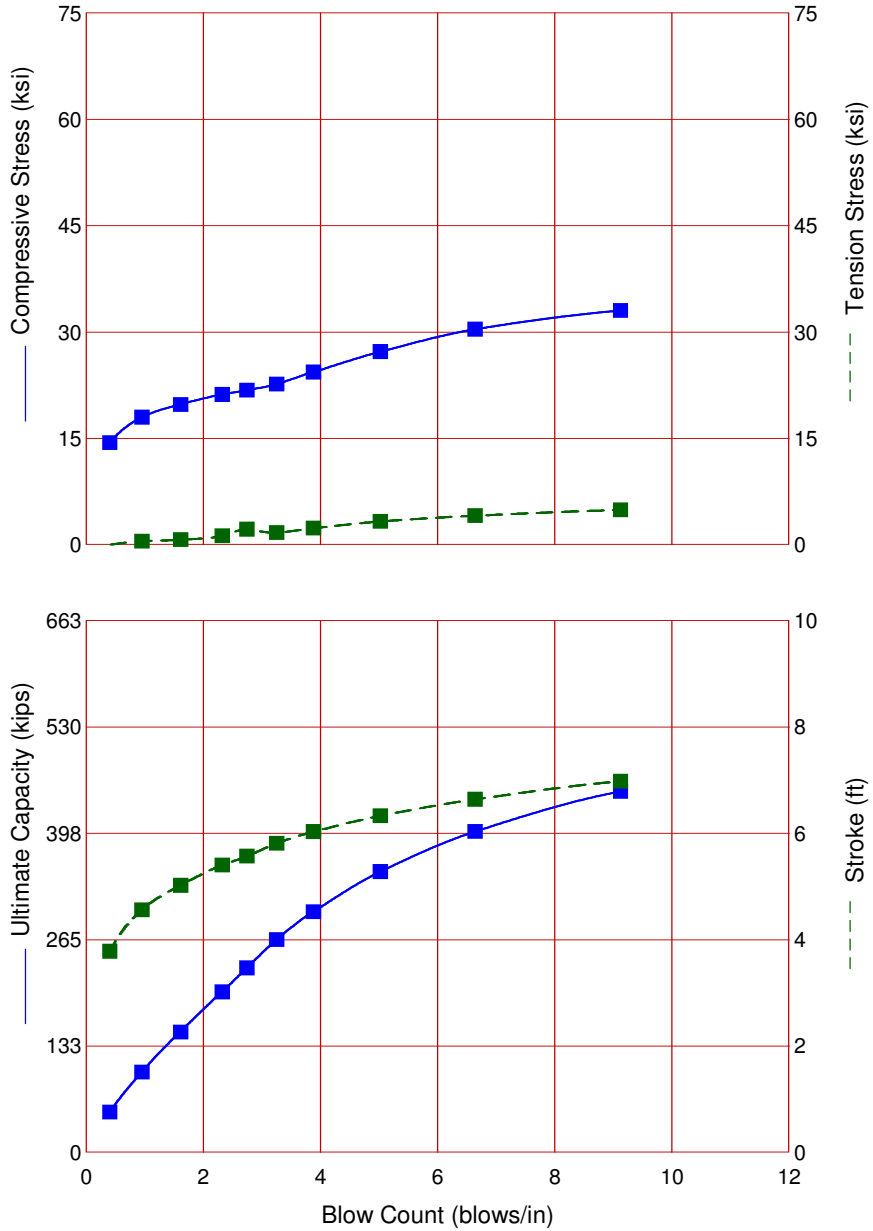

APE D 19-42

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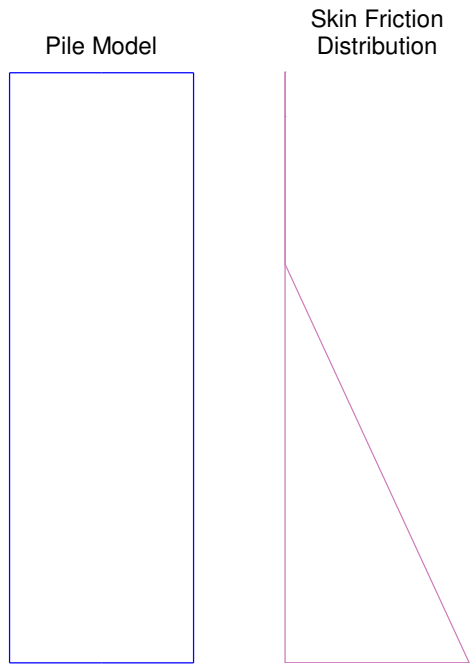

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Ultimate Capacity kips	Maximum Compression Stress ksi	Maximum Tension Stress ksi	Blow Count blows/in	Stroke ft	Energy kips-ft
50.0	14.38	0.00	0.4	3.78	16.51
100.0	17.97	0.50	1.0	4.56	14.63
150.0	19.78	0.72	1.6	5.02	13.70
200.0	21.20	1.24	2.3	5.40	13.61
230.0	21.81	2.17	2.8	5.57	13.63
265.0	22.64	1.70	3.3	5.81	13.95
300.0	24.35	2.33	3.9	6.03	14.24
350.0	27.23	3.29	5.0	6.33	14.76
400.0	30.39	4.11	6.6	6.64	15.34
450.0	33.04	4.91	9.1	6.98	16.02