GZA
GeoEnvironmental, Inc.

Engineers and Scientists

April 2, 2014
File No. 02.0171952.00-C, PC

Mr. Chad Contaldi
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Massachusetts
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http://www.gza.com

Re: Wave Equation Analyses
Pittsfield ER BRF 022-1 (23)
Pittsfield. 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. 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 - 80-foot long, HP 12x84 Grade 50 steel piles are modeled. The cross-sectional area for this pile type is 24.6 square inches. The specified nominal axial resistance of 385 kips is based upon dividing the maximum factored axial pile load of 250 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, a frictional resistance profile and an end bearing soil resistance profile is modelled.

Frictional Profile

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

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- 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:

Nominal Pile Resistance: 385 kips

Pile Hammer	Resistance Profile	Blow Count (bpi)	Ram Stroke (ft)	Compressive Stress (ksi)	Transfer Energy (kip-ft)
APE D19-42	Friction	6 bpi	8.5 ft.	26.1 ksi	22.5 kip-ft
	End Bearing	5 bpi	8.4 ft.	31.5 ksi	23.5 kip-ft

The results tabulated above indicate that the APE D19-42 open-end diesel hammer can drive the specified HP12x84 Grade 50 steel piles to a nominal resistance of 385 kips without overstressing the pile section. Based on the above results, the preliminary recommended driving resistance is 6 blows per inch with the APE D19-42 providing a ram stroke of approximately 8.5 feet. The maximum estimated driving stress of 31.5 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 driving criterion may be refined based on the results of the dynamic pile test program.

Please note that the project documents imply that the specified HP12x84 steel piles are to be driven to bedrock. Based on our review of the contract boring logs and our experience with this type of driving condition, the piles are expected to take-up abruptly as they develop end-bearing on competent bedrock. 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.

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

Very truly yours,

GZA GEOENVIRONMENTAL, INC.

Michael J. Deery
Project Engineer

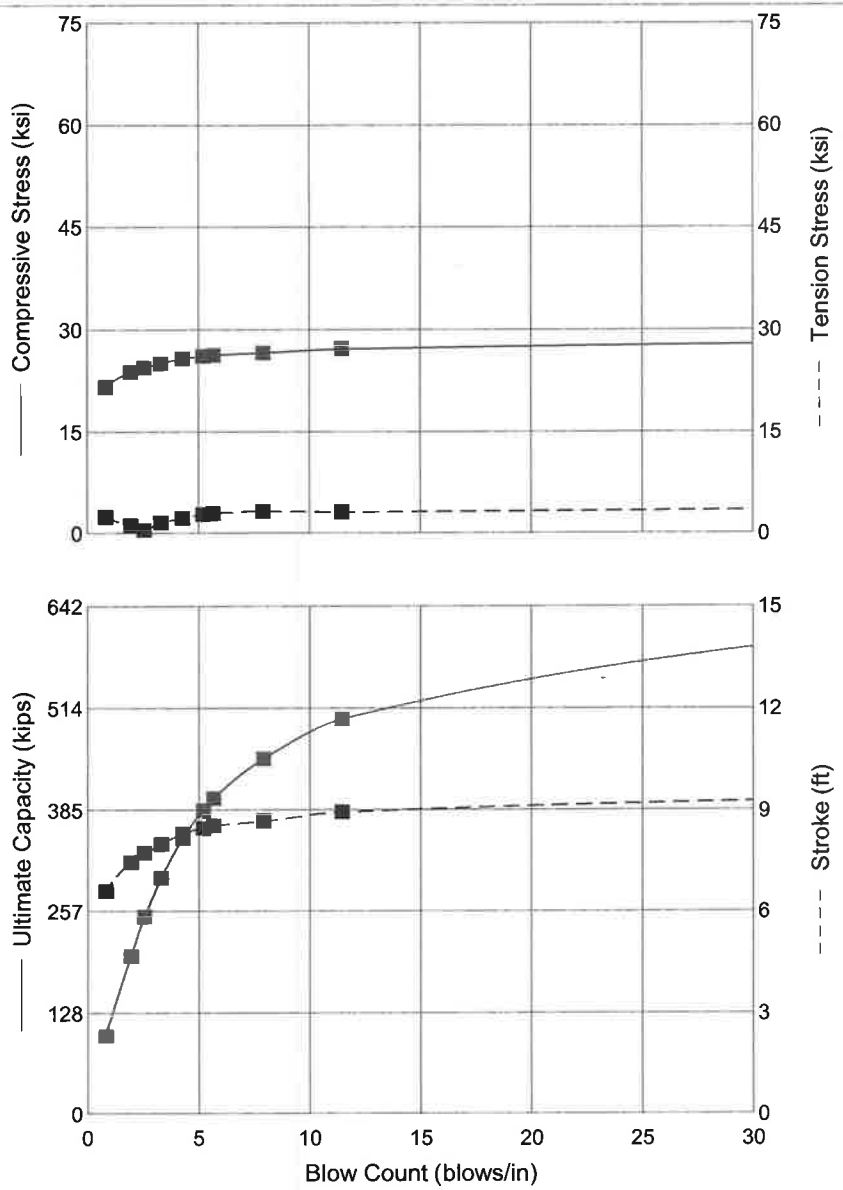
Bradford W. Roberts
Consultant / Reviewer

John E. Regan
Principal

Attachments: Wave Equation Analysis Results

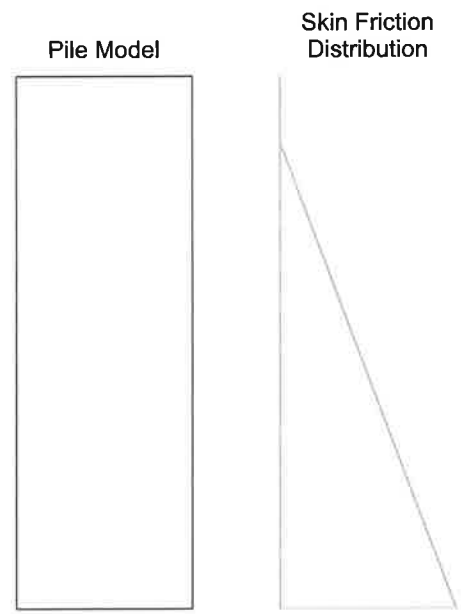
GZA GeoEnvironmental Inc.
Pittsfield D19-42 D19-42 80'HP12x84 FRvc

01-Apr-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	0.040	in
Skin Damping	0.200	sec/ft
Toe Damping	0.150	sec/ft
Pile Length	80.00	ft
Pile Penetration	70.00	ft
Pile Top Area	24.60	in2



Res. Shaft = 50 %
(Proportional)

GZA GeoEnvironmental Inc.
Pittsfield D19-42 D19-42 80'HP12x84 FRvc

01-Apr-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	21.55	2.43	0.8	6.61	21.95
200.0	23.77	1.19	2.0	7.48	20.81
250.0	24.43	0.51	2.6	7.75	21.06
300.0	25.05	1.59	3.3	8.01	21.53
350.0	25.76	2.25	4.3	8.32	22.22
385.0	26.11	2.77	5.2	8.47	22.54
400.0	26.28	2.94	5.7	8.55	22.71
450.0	26.61	3.26	7.9	8.69	22.97
500.0	27.15	3.15	11.5	8.94	23.56
600.0	27.95	3.47	32.9	9.30	24.39

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Pittsfield D19-42 D19-42 80'HP12x84 FRcc

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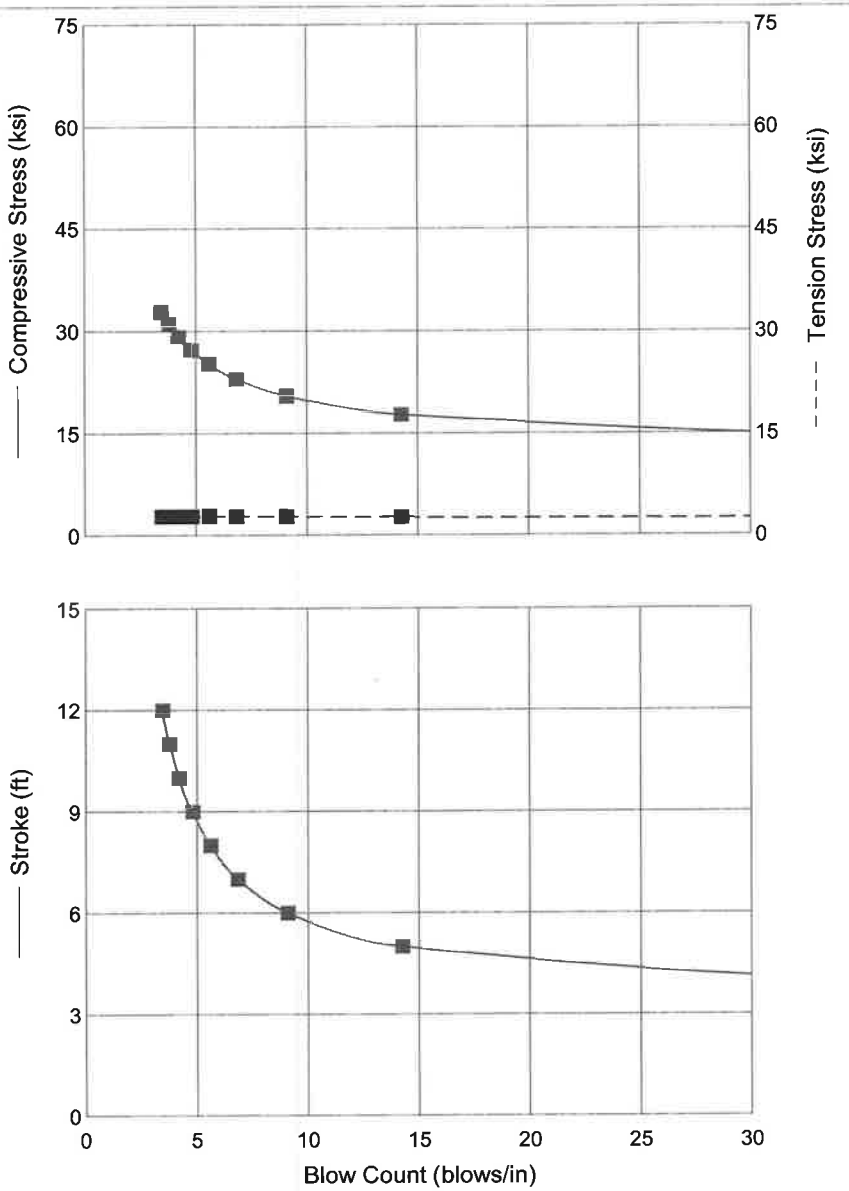
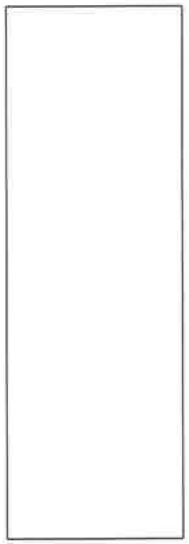
GRLWEAP Version 2010



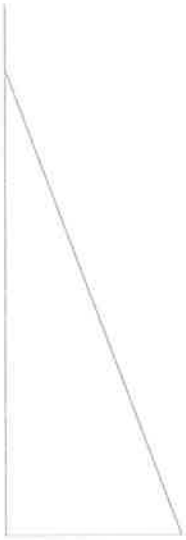
APE D 19-42

Capacity	385.0	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	0.040	in
Skin Damping	0.200	sec/ft
Toe Damping	0.150	sec/ft
Pile Length	80.00	ft
Pile Penetration	70.00	ft
Pile Top Area	24.60	in2

Pile Model



Skin Friction Distribution



Res. Shaft = 50 %
(Proportional)

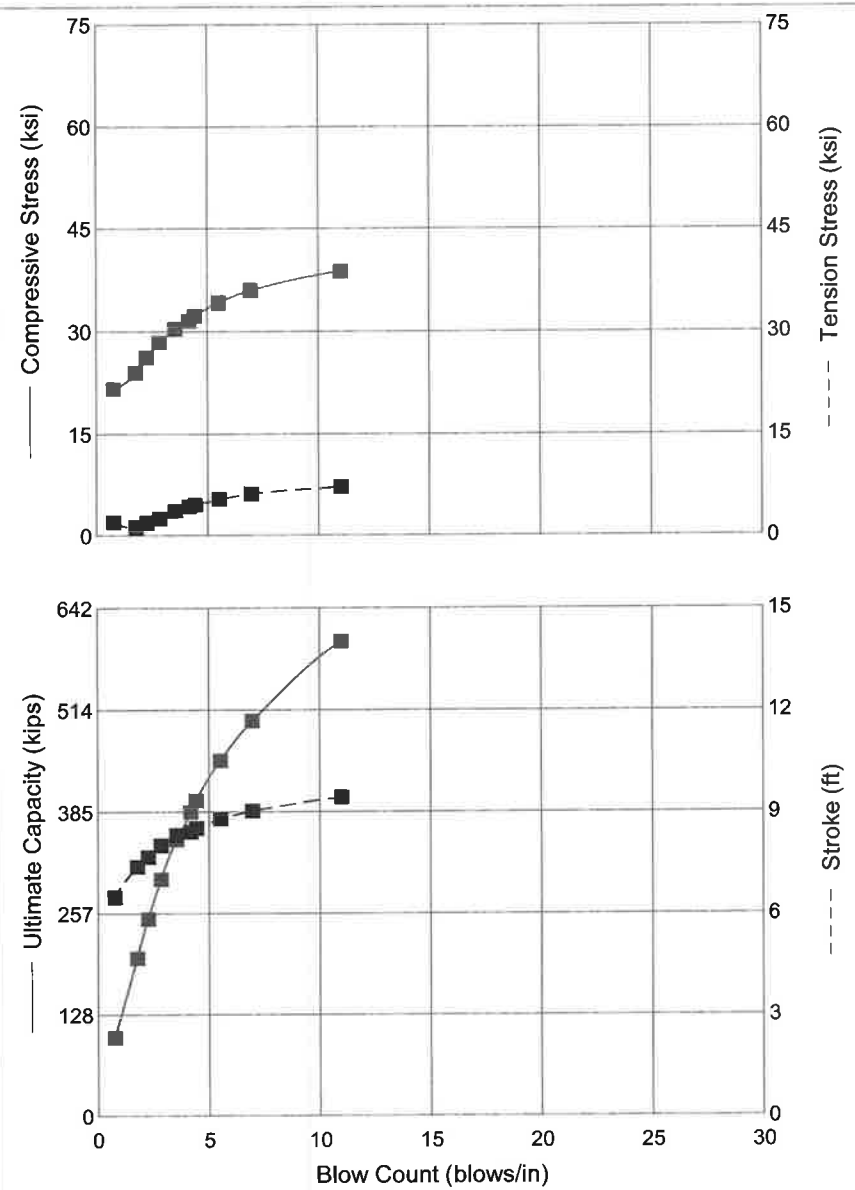
GZA GeoEnvironmental Inc.
Pittsfield D19-42 D19-42 80'HP12x84 FRcc

01-Apr-2014
GRLWEAP Version 2010

Ultimate Capacity kips	Maximum Compression Stress ksi	Maximum Tension Stress ksi	Blow Count blows/in	Stroke ft	Energy kips-ft
385.0	12.63	2.44	9999.0	3.00	6.26
385.0	14.59	2.52	37.4	4.00	9.53
385.0	17.72	2.62	14.3	5.00	12.54
385.0	20.43	2.68	9.1	6.00	15.50
385.0	22.87	2.71	6.9	7.00	18.41
385.0	25.10	2.76	5.6	8.00	21.24
385.0	27.19	2.79	4.8	9.00	24.04
385.0	29.15	2.80	4.3	10.00	26.83
385.0	30.99	2.79	3.8	11.00	29.63
385.0	32.72	2.77	3.5	12.00	32.39

GZA GeoEnvironmental Inc.
Pittsfield D19-42 D19-42 80'HP12x84 EBvc

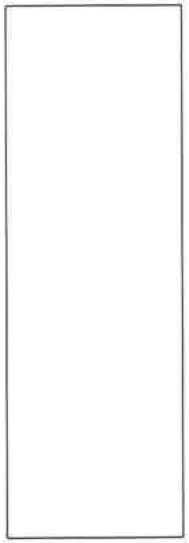
01-Apr-2014
GRLWEAP Version 2010



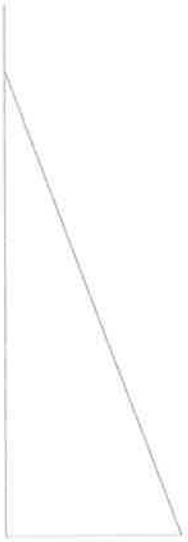
APE D 19-42

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	0.040	in
Skin Damping	0.200	sec/ft
Toe Damping	0.150	sec/ft
Pile Length	80.00	ft
Pile Penetration	70.00	ft
Pile Top Area	24.60	in2

Pile Model



Skin Friction Distribution



Res. Shaft = 10 %
(Proportional)

GZA GeoEnvironmental Inc.
Pittsfield D19-42 D19-42 80'HP12x84 EBvc

01-Apr-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	21.59	1.92	0.8	6.48	22.25
200.0	23.93	1.19	1.8	7.38	21.49
250.0	26.21	1.85	2.3	7.67	21.77
300.0	28.41	2.45	2.9	8.01	22.40
350.0	30.38	3.60	3.6	8.31	23.23
385.0	31.53	4.24	4.2	8.41	23.49
400.0	32.27	4.52	4.4	8.52	23.81
450.0	34.27	5.31	5.5	8.79	24.55
500.0	36.01	6.14	7.0	9.03	25.20
600.0	38.75	7.13	11.0	9.43	26.20

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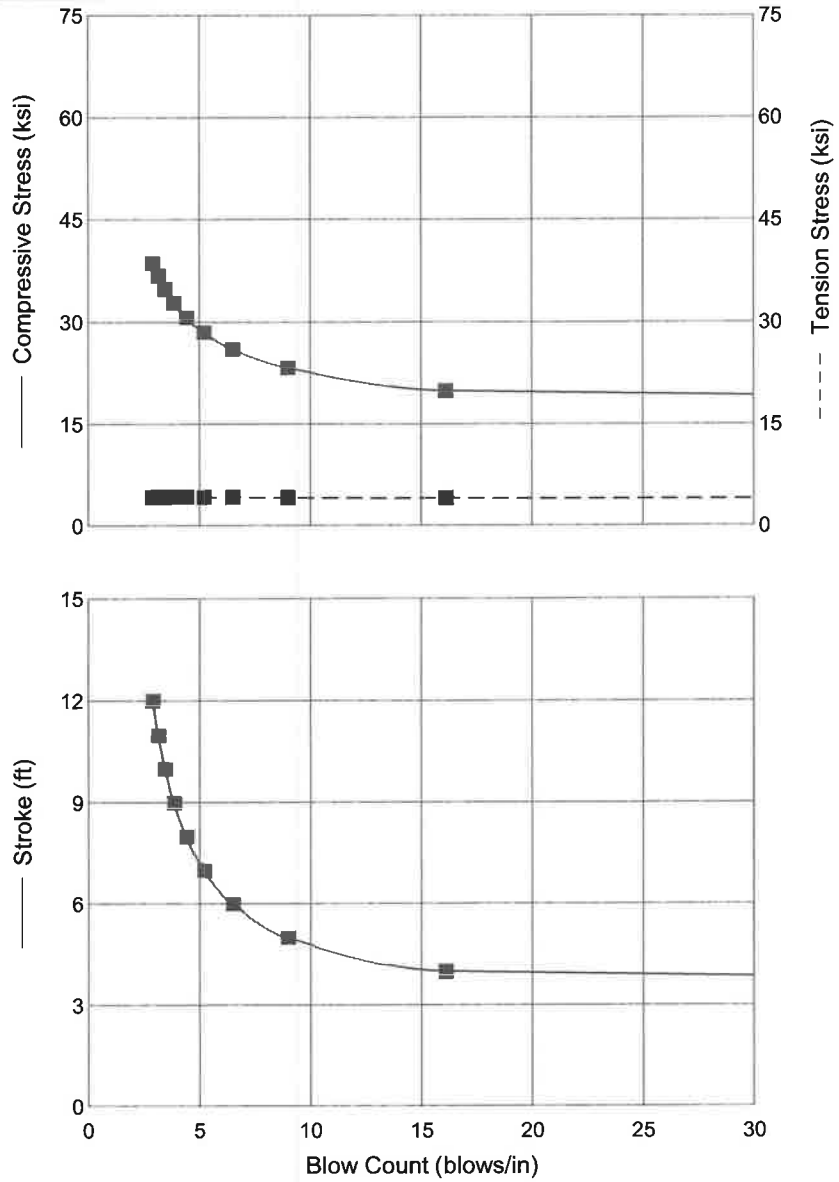

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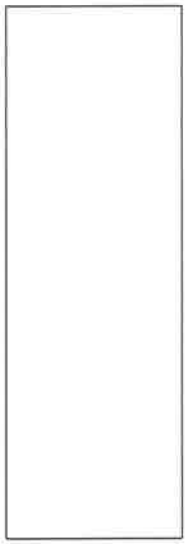
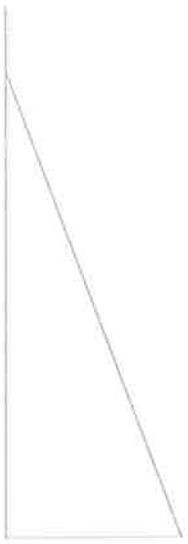


Skin Friction Distribution



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GRLWEAP Version 2010

Ultimate Capacity kips	Maximum Compression Stress ksi	Maximum Tension Stress ksi	Blow Count blows/in	Stroke ft	Energy kips-ft
385.0	15.37	3.82	154.7	3.00	6.87
385.0	19.92	4.08	16.1	4.00	10.27
385.0	23.29	4.18	9.0	5.00	13.43
385.0	26.04	4.22	6.5	6.00	16.46
385.0	28.50	4.24	5.2	7.00	19.41
385.0	30.68	4.24	4.4	8.00	22.28
385.0	32.85	4.24	3.9	9.00	25.20
385.0	34.82	4.22	3.5	10.00	28.04
385.0	36.75	4.19	3.2	11.00	30.87
385.0	38.59	4.17	2.9	12.00	33.69