

**GZA
GeoEnvironmental, Inc.**

*Engineers and
Scientists*

July 16, 2015
File No. 02.0172414.00

Mr. Arty St. Onge
A.L. St. Onge Contractor, Inc.
P.O. Box 65
82 Fuller Road
Montgomery, Vermont 05470-0065

Re: Wave Equation Analyses
Middlesex BRF 024-1(37)
Middlesex, Vermont

Dear Mr. St. Onge:

At your request, GZA GeoEnvironmental, Inc. (GZA) has performed the following Wave Equation Analyses (WEAP) for the above referenced project. These analyses were performed in general accordance with the project specifications. A copy of the GRLWEAP output is attached and the WEAP input parameters are summarized below:

- Hammer- 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 APE 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 5.4 feet, 7.6 feet, 9.0 feet, and 11.4 feet (open) yielding rated energies of 22,721 foot-lbs., 31,715 foot-lbs., 37,868 foot-lbs., and 47,335 foot-lbs, respectively. The APE D19-42 is modeled operating on fuel setting 3 (9.0 foot rated stroke) to develop the required nominal resistance at a reasonable penetration resistance without overstressing the pile section at the final set. The hammer cushioning material reportedly consists of 2 inches of nylon. No pile cushioning material is required for the pile type detailed below.
- Pile - 40-foot long and 60 foot-long, HP 12x84 Grade 50 steel piles are modeled at the Abutment 1 and Abutment 2 substructures, respectively. The cross-sectional area for this pile type is 24.6 square inches. The nominal resistance of 432 kips is based on dividing the maximum factored load of 280 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 soil resistance profile varies for each abutment substructure.

Abutment 1

The soil resistance profile for Abutment 1 is modeled as 80% end bearing and 20% skin friction triangularly distributed along the embedded pile length.



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Abutment 2

The soil resistance profile for Abutment 2 is modeled as 70% end bearing and 30% skin friction triangularly distributed along the along the embedded pile length.



- Analysis Two analyses model the above hammer-pile-soil system.
 1. Variable capacity analyses which develop a driving resistance based on the most efficient hammer stroke with the APE D19-42 operating on fuel setting 3.
 2. Constant capacity analyses which develop a driving resistance based on a varied hammer stroke.

- Results The preliminary recommended driving resistance is tabulated below.

Abutment	Nominal Resistance (kips)	Blow Count (bpi)	Ram Stroke (ft)	Driving Stress (ksi)	Transfer Energy (kip-ft)
1	432 kips	5 bpi	8.1 ft	31.7 ksi	19.4 ksi
2		6 bpi	7.9 ft	27.9 ksi	20.1 ksi

Notes

1. The maximum allowable driving stress is 45 ksi for Grade 50 steel HP piles.
2. The APE D19-42 is modeled operating on the fuel setting 3 (9.0 foot rated stroke).

The WEAP results tabulated above indicate that the APE D19-42 diesel can demonstrate the required nominal resistance of 432 kips without overstressing the pile section. The preliminary driving criterion determined by the above WEAP analysis is 5 blows per inch and 6 blows per inch with the APE D19-42 operating on fuel setting 3 and providing an approximate 8.0-foot ram stroke for the Abutment 1 and Abutment 2 substructures, respectively. We recommend that the above driving criteria be developed for a minimum of three (3) consecutive inches. 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.

The project documents specify that the HP12x84 piles shall have a minimum embedment of 30 feet measured from the bottom of the pile cap or be driven to bedrock. The contract subsurface investigation indicates cobbles and boulders in the overburden soils. The Engineer is advised that the piles may shift out of alignment or develop end bearing on the boulders as the pile tip penetrates into or through a boulder stratum. Based on our experience with this type of end bearing driving condition, the piles may take-up abruptly as they develop end-bearing on large boulders or 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 (10 blows/0.5") penetration with the APE D19-42 operating on fuel setting 3 and providing an approximate 8.0 foot ram stroke.

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

Very truly yours,
GZA GEOENVIRONMENTAL, INC.



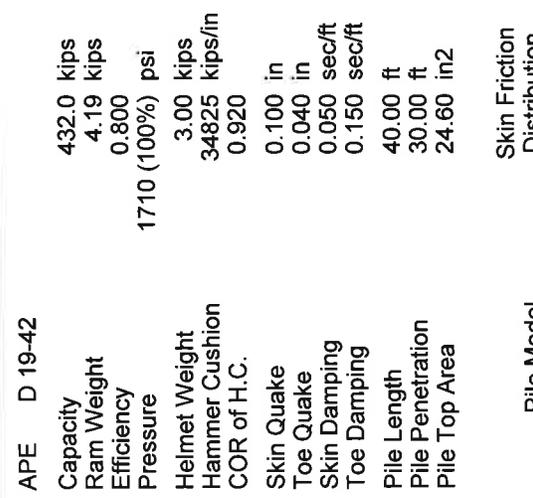
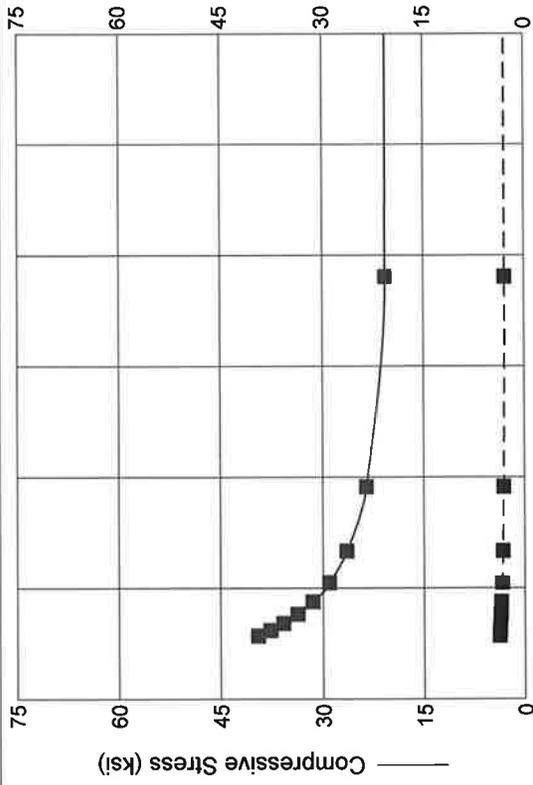

Michael Deery
Project Engineer


Bradford W. Roberts
Consultant/Reviewer


John E. Regan
Principal

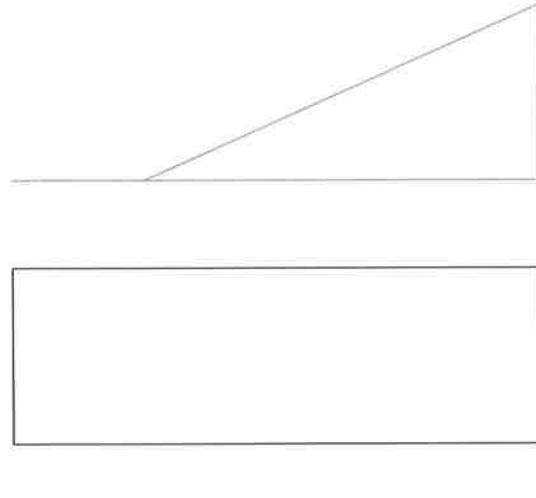
Attachments: Wave Equation Analysis Results

ABUTMENT 1



APE D 19-42

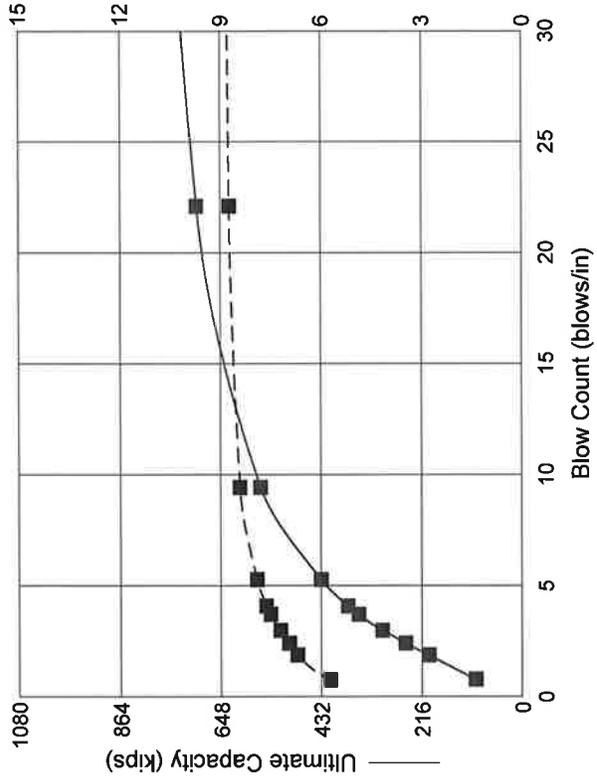
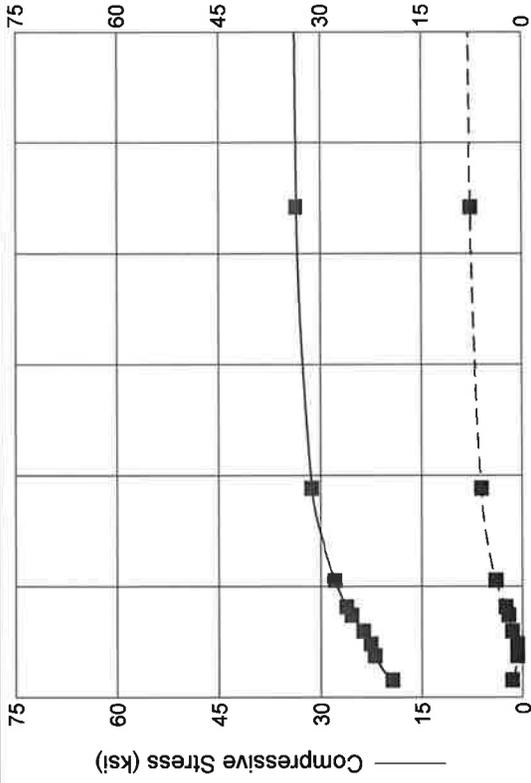
Capacity	432.0 kips
Ram Weight	4.19 kips
Efficiency	0.800
Pressure	1710 (100%) psi
Helmet Weight	3.00 kips
Hammer Cushion	34825 kips/in
COR of H.C.	0.920
Skin Quake	0.100 in
Toe Quake	0.040 in
Skin Damping	0.050 sec/ft
Toe Damping	0.150 sec/ft
Pile Length	40.00 ft
Pile Penetration	30.00 ft
Pile Top Area	24.60 in ²



Res. Shaft = 20 %
(Proportional)

Ultimate Capacity kips	Maximum Compression Stress ksi	Maximum Tension Stress ksi	Blow Count blows/in	Stroke ft	Energy kips-ft
432.0	17.92	2.57	9999.0	3.00	4.94
432.0	20.67	2.96	19.0	4.00	8.11
432.0	23.52	3.14	9.6	5.00	11.12
432.0	26.44	3.28	6.7	6.00	14.05
432.0	29.06	3.39	5.3	7.00	16.94
432.0	31.52	3.53	4.4	8.00	19.83
432.0	33.73	3.63	3.8	9.00	22.64
432.0	35.82	3.69	3.4	10.00	25.45
432.0	37.68	3.73	3.1	11.00	28.23
432.0	39.54	3.77	2.9	12.00	31.01

ABUTMENT 2



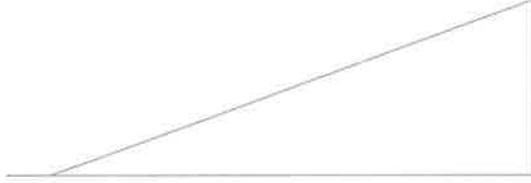
APE D 19-42
 Ram Weight 4.19 kips
 Efficiency 0.800
 Pressure 1539 (90%) psi
 Helmet Weight 3.00 kips
 Hammer Cushion 34825 kips/in
 COR of H.C. 0.920
 Skin Quake 0.100 in
 Toe Quake 0.040 in
 Skin Damping 0.050 sec/ft
 Toe Damping 0.150 sec/ft
 Pile Length 60.00 ft
 Pile Penetration 55.00 ft
 Pile Top Area 24.60 in²

4.19 kips
 0.800
 1539 (90%) psi
 3.00 kips
 34825 kips/in
 0.920
 0.100 in
 0.040 in
 0.050 sec/ft
 0.150 sec/ft
 60.00 ft
 55.00 ft
 24.60 in²

Pile Model

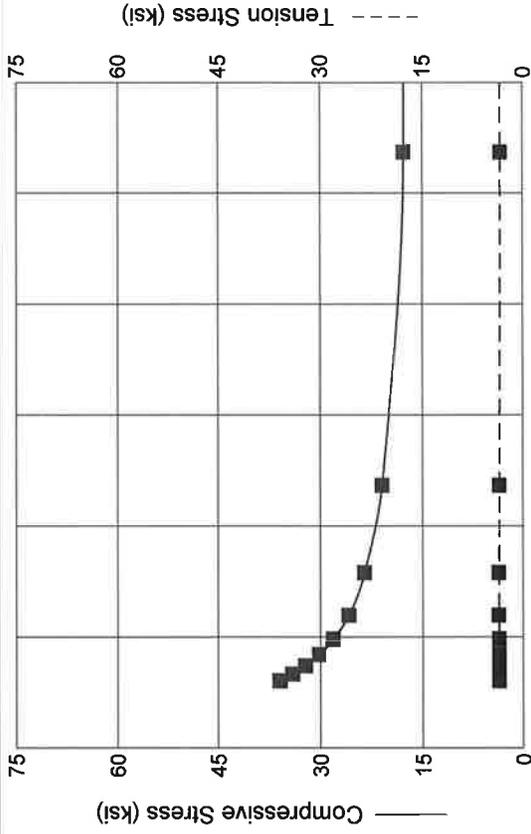


Skin Friction Distribution



Res. Shaft = 30 %
 (Proportional)

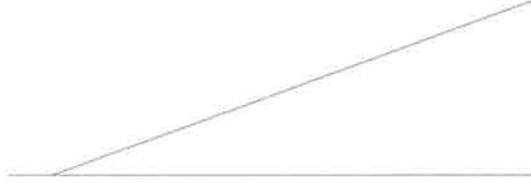
Ultimate Capacity kips	Maximum Compression Stress ksi	Maximum Tension Stress ksi	Blow Count blows/in	Stroke ft	Energy kips-ft
100.0	19.40	1.54	0.8	5.73	19.39
200.0	22.00	0.81	1.9	6.71	18.48
250.0	22.62	0.78	2.4	6.95	18.28
300.0	23.71	1.54	3.0	7.21	18.66
351.0	25.47	2.10	3.7	7.51	19.13
374.0	26.23	2.49	4.1	7.64	19.36
432.0	27.90	3.96	5.3	7.92	20.10
562.0	31.31	6.06	9.4	8.43	21.41
700.0	33.53	7.70	22.1	8.74	22.14
800.0	34.36	8.63	54.6	8.89	22.50



APE D 19-42

Capacity	432.0 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	0.050 sec/ft
Toe Damping	0.150 sec/ft
Pile Length	60.00 ft
Pile Penetration	55.00 ft
Pile Top Area	24.60 in ²

Skin Friction
 Distribution



Res. Shaft = 30 %
 (Proportional)

Ultimate Capacity kips	Maximum Compression Stress ksi	Maximum Tension Stress ksi	Blow Count blows/in	Stroke ft	Energy kips-ft
432.0	15.48	3.11	9999.0	3.00	5.88
432.0	17.72	3.42	26.8	4.00	9.15
432.0	20.96	3.61	11.8	5.00	12.25
432.0	23.57	3.68	7.9	6.00	15.19
432.0	25.86	3.68	6.0	7.00	18.13
432.0	28.12	3.66	4.9	8.00	20.99
432.0	30.21	3.67	4.2	9.00	23.83
432.0	32.23	3.66	3.7	10.00	26.63
432.0	34.12	3.65	3.3	11.00	29.45
432.0	35.95	3.65	3.0	12.00	32.24