**AGENCY OF TRANSPORTATION** **OFFICE MEMORANDUM**

**To:** Kristin Higgins, Structures Project Manager

**From:** Callie Ewald, P.E., Geotechnical Engineer, via Christopher C. Benda, P.E. Soils and Foundations Engineer

**Date:** January 11th, 2013

**Subject:** Hancock ER BRF 0174(16) Wave Equation Analysis

The following summarizes the results of our wave equation analysis conducted at your request for the piles proposed for the Hancock ER BRF 0174(16) project.

We received a copy of the wave equation analysis provided to Tim Parent of Parent Construction that was conducted by David Gifford of H.B. Fleming, Inc. Mr. Gifford performed wave equation analyses for the pile and hammer specified for use in the Hancock ER BRF 0174(16) project. Two single acting diesel hammers were requested for analysis, the MKT DE-42 with a rated energy of 42,000 ft-lbs and the APE D19-42 with a rated energy of 42,800 ft-lbs. These hammers were evaluated for the pile-soil system for the Hancock ER BRF 0174(16) site only.

The results of our analysis for the MKT DE-42 hammer differed slightly from H.B. Fleming's results. This was due to the differing ram weights used in the analysis. Both the pile equipment data sheet and the manufacturer sheet provided for the hammer specified a new ram weight of 4,200 pounds, which was used in our analysis. It appears an old ram weight of 3,500 lbs was used in H.B. Fleming's analysis. Aside from this discrepancy, small differences between blow counts will be verified with PDA testing in the field.

The hammer-pile-soil systems analyzed are given below:

Pile: The piles, steel HP 12x74 sections, were modeled as being 45 feet in length at both abutments. The cross sectional area was set equal to 21.8 $in^2$. The nominal resistance is 414 kips, based on a design load of 269.1 kips and a resistance factor of 0.65. The maximum allowable driving stresses for Grade 50 steel is 45 ksi, as calculated by $0.9f_y$.

Hammers: The MKT DE-42 single-acting diesel impact hammer was analyzed operating at an 10.0 foot ram stroke to limit driving stresses. The DE-42 has a ram weight of 4,200 lbs and maximum rated stroke of 10.5 feet, corresponding to a rated energy of 42,000 ft-lbs.

The APE D19-42 single-acting diesel impact hammer was analyzed operating at an 10.16 foot ram stroke to limit driving stresses. The D19-42 has a ram weight of 4,190 lbs and maximum rated stroke of 10.25 feet, corresponding to a rated energy of 42,800 ft-lbs.

Cushion: A hammer cushion was specified for each hammer. The MKT DE-42 was specified as having a total thickness of 2.5 inches of Hamortex. The cross sectional area and the modulus of elasticity were reported on the pile equipment data sheet as 285 $in^2$ and 125 ksi, respectively. The APE D-19 was specified as having a total thickness of 2.0 inches of Monocast MC901. The cross sectional area and the modulus of elasticity were reported on the pile equipment data sheet as 397.6 $in^2$ and 285 ksi, respectively. The

coefficient of restitution was documented to be 0.8 for both hammer cushions.

Soil: For the pile-hammer system, the resistance during driving encountered by the pile was modeled as 80% end bearing and 20% skin friction triangularly distributed along the lower 41 feet of the pile.

Variable capacity analyses were conducted, which are used to determine a driving resistance based on the most efficient stroke. The results of the two analyses are enclosed with this memo.

In order to drive the specified piles to the nominal resistance of 414 kips, the anticipated blows per inch and corresponding minimum ram strokes are provided below in Table 1.

**Table 1.** GRLWeap Analysis Output

| Hammer Type | Blows per inch (BPI) | Ram stoke |
|---|---|---|
| MKT DE-42 | 7 | 9.0 ft |
| APE D19-42 | 5 | 9.5 ft |

Preliminarily, the DE-42 is anticipated to utilize 7 BPI in order to drive the specified H-piles to the required nominal resistance. Please note this differs from H.B. Fleming's recommendation of 9 BPI because out analysis took into account a new ram weight of 4,200 pounds, rather than 3,500 pounds. The 2011 VTrans Standard Specifications for Construction, Section 504.02(b), which states the pile driving equipment must be capable of driving the pile to the required resistance at blow counts between 3 and 15 BPI. **Based upon this information and the WEAP analysis, both the MKT DE-42 and APE D-19 hammers should be able to drive the steel HP 12x74 piles to the desired resistance and stay within the specifications.**

The initial driving criterion for each hammer is shown above in Table 1. This driving criterion must be maintained for 3 consecutive inches. At these blow counts, the stresses in the pile are expected to remain below 45 ksi. A saximeter is required to be on site to monitor the driving process at each substructure. As the piles will be driven to bedrock, and may take up abruptly; we recommend using a refusal criterion as 10 blows per half inch when piles are on suspected bedrock.

Please record the serial number of the hammer prior to our arrival. Also, it is important to note that the thickness of the prescribed Hamortex or Monocast cushions should be inspected prior to driving any piles. **If the thickness of the hammer cushion has decreased by 25%, then the cushion should be replaced, per Agency Specifications.** Generally, the best time to inspect the hammer cushion is when the hammer first arrives on the job, and is placed in the leads.

The orientation and verticality of each integral abutment pile is especially critical because the abutments are designed as integral abutments rather than traditional abutments on H-piles. Each pile should be reinforced against damage with a reinforced pile point (driving shoe).

Attachments: Wave Equation Results – Variable Capacity Charts (4 pages)

cc: Resident Engineer
CCB/Project File
CEE

MKT DE-42

Vermont Agency of Transportation
Hancock ER BRF 0174(16)

09-Jan-2013
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 | 23.57 | 1.47 | 0.9 | 6.10 | 17.34 |
| 200.0 | 27.54 | 0.00 | 2.5 | 7.49 | 15.49 |
| 300.0 | 32.56 | 0.79 | 4.2 | 8.28 | 16.05 |
| 350.0 | 35.60 | 1.09 | 5.2 | 8.62 | 16.61 |
| 400.0 | 37.92 | 1.51 | 6.5 | 8.82 | 17.03 |
| 414.0 | 38.51 | 1.62 | 6.9 | 8.88 | 17.18 |
| 425.0 | 39.18 | 1.73 | 7.1 | 9.02 | 17.49 |
| 450.0 | 39.94 | 1.82 | 8.1 | 9.05 | 17.51 |
| 500.0 | 42.02 | 1.57 | 9.8 | 9.37 | 18.22 |
| 600.0 | 44.82 | 2.77 | 15.2 | 9.74 | 18.99 |

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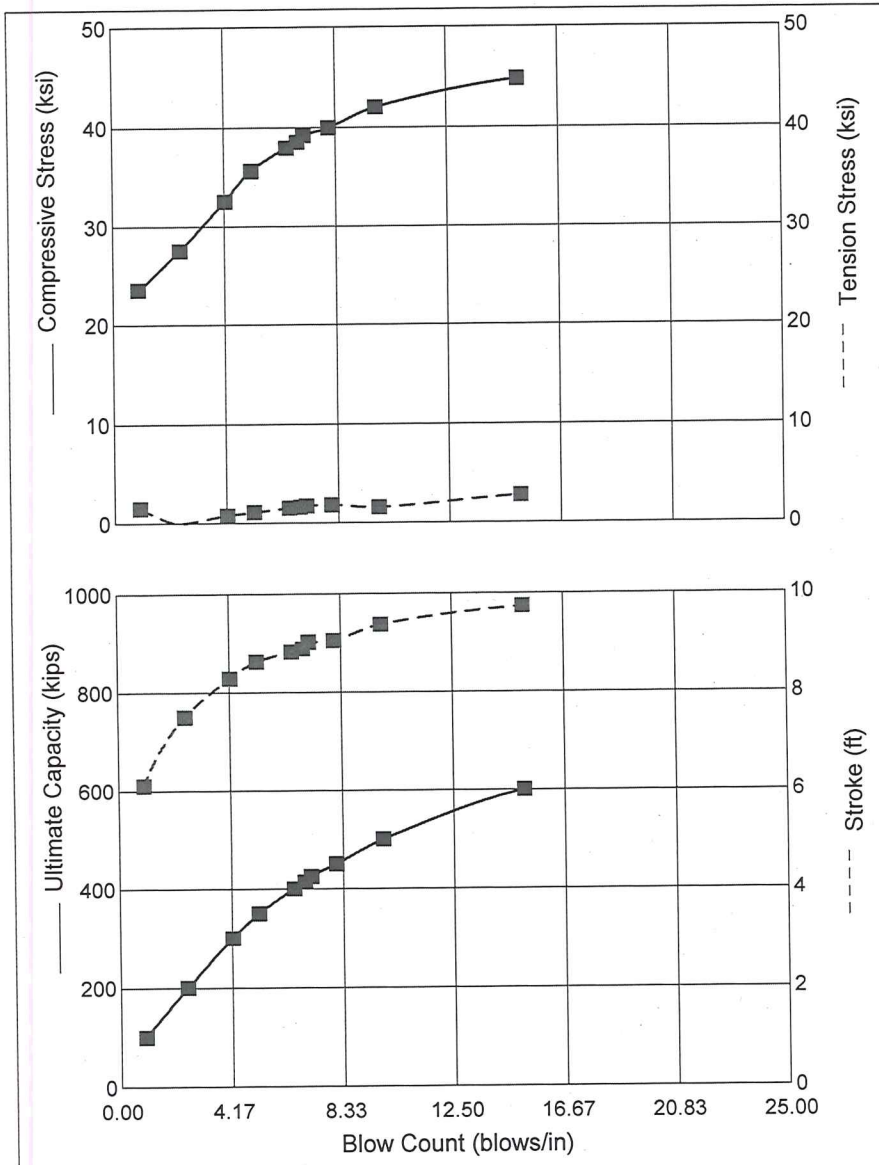
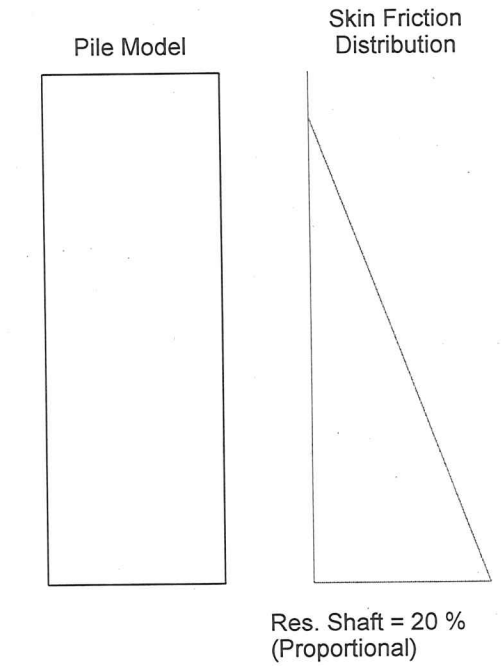



MKT DE 42/35

| | | |
|---|---|---|
| Ram Weight | 4.20 | kips |
| Efficiency | 0.800 | |
| Pressure | 1316 (100%) | psi |
| Helmet Weight | 1.20 | kips |
| Hammer Cushion | 14250 | kips/in |
| COR of H.C. | 0.800 | |
| Skin Quake | 0.100 | in |
| Toe Quake | 0.050 | in |
| Skin Damping | 0.050 | sec/ft |
| Toe Damping | 0.150 | sec/ft |
| Pile Length | 45.00 | ft |
| Pile Penetration | 41.00 | ft |
| Pile Top Area | 21.80 | in2 |



APE D19-42

Vermont Agency of Transportation
Hancock ER BRF 0174(16)

09-Jan-2013
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 | 25.26 | 0.59 | 0.8 | 6.17 | 22.73 |
| 200.0 | 29.97 | 0.14 | 1.8 | 7.78 | 21.05 |
| 300.0 | 35.69 | 0.64 | 3.0 | 8.76 | 21.46 |
| 350.0 | 38.94 | 1.26 | 3.6 | 9.15 | 21.88 |
| 400.0 | 41.68 | 2.00 | 4.5 | 9.46 | 22.49 |
| 414.0 | 42.41 | 2.16 | 4.8 | 9.56 | 22.72 |
| 425.0 | 42.98 | 2.26 | 4.9 | 9.64 | 22.97 |
| 450.0 | 44.15 | 2.46 | 5.5 | 9.80 | 23.31 |
| 500.0 | 46.96 | 2.41 | 6.5 | 10.29 | 24.52 |
| 600.0 | 50.59 | 2.08 | 9.3 | 10.83 | 25.83 |

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Hancock ER BRF 0174(16)

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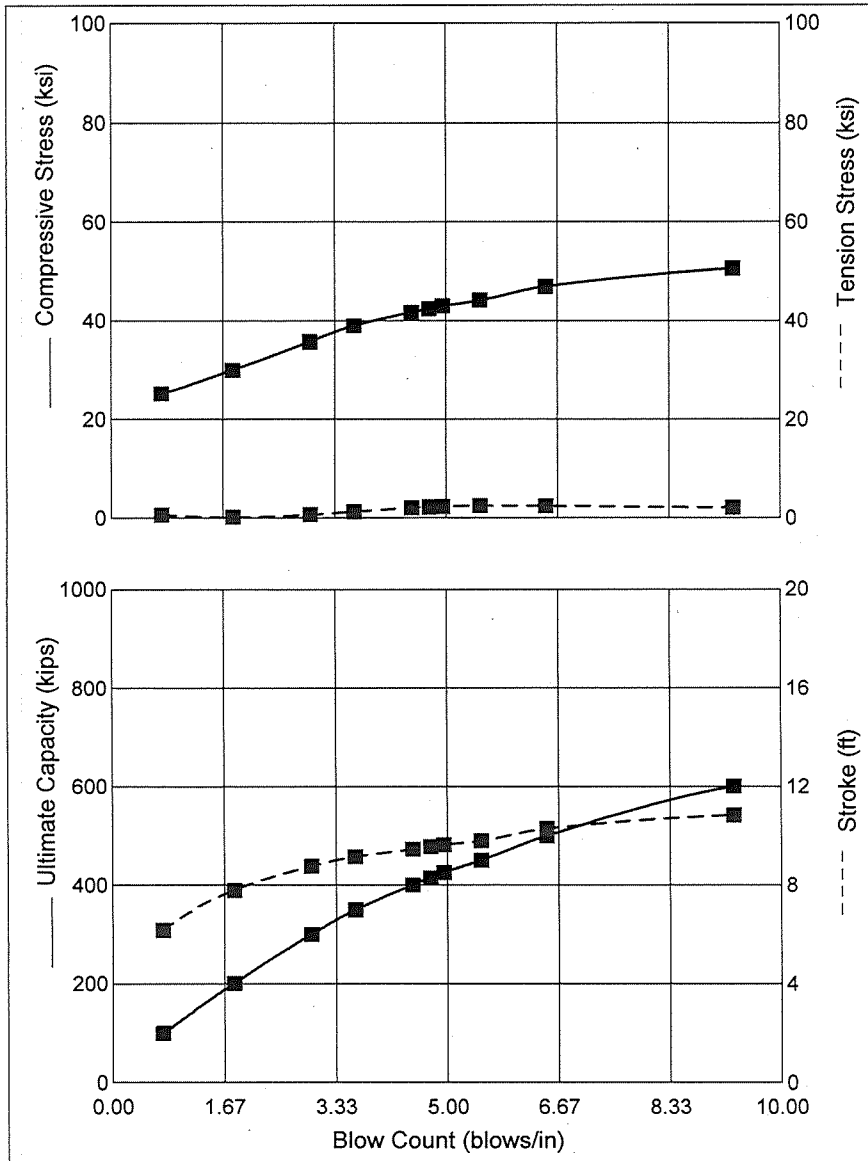
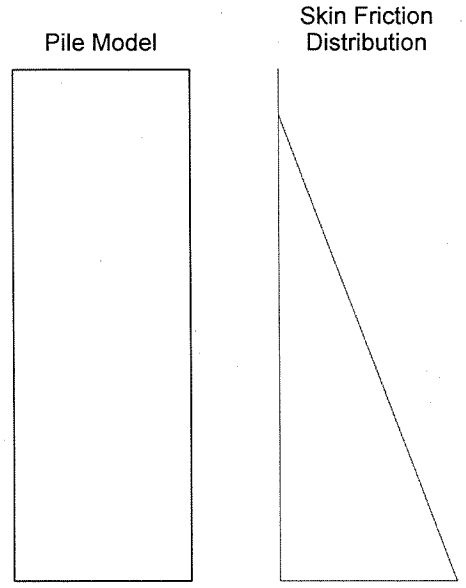



APE D 19-42

| | | |
|---|---|---|
| Ram Weight | 4.19 | kips |
| Efficiency | 0.800 | |
| Pressure | 1710 (100%) | psi |
| Helmet Weight | 1.35 | kips |
| Hammer Cushion | 56658 | kips/in |
| COR of H.C. | 0.800 | |
| Skin Quake | 0.100 | in |
| Toe Quake | 0.050 | in |
| Skin Damping | 0.050 | sec/ft |
| Toe Damping | 0.150 | sec/ft |
| Pile Length | 45.00 | ft |
| Pile Penetration | 41.00 | ft |
| Pile Top Area | 21.80 | in2 |




Res. Shaft = 20 %
(Proportional)