METHOD OF STATEMENT FOR WAVE PROPAGATION PILE TESTING

High Strain Dynamic Test,

Low Strain Integrity Test

&

Cross Hole Sonic Test

According to the American Standards

ASTM D4945-08, ADTM D5882-07 and ASTM D6760-08

مكتب اللقاء الهندسي لفحص الركائز

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Pile Driving Analyzer®
Pile Dynamics, Inc.

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Introduction

In the 1950's, E.A. Smith of the Raymond Pile Driving Company studied wave propagation on slender rods, and developed a numerical analysis method to predict the capacity versus blow count relationship and investigate pile driving stresses. The model mathematically represents the hammer and all its accessories (ram, cap, cap block), as well as the pile, as a series of lumped masses and springs in a one-dimensional analysis. The soil response for each pile segment is modeled as viscoelastic-plastic. All components of the system are realistically modeled. The analysis begins with the hammer ram falling and attaining an initial velocity at impact. This method is the best technique for predicting the relationship of pile capacity and blow counts (or set per blow), and the only method available to predict driving stresses. Improvements to Smith's method to incorporate a thermodynamic diesel hammer model and residual stresses. The wave equation approach is an excellent predictive tool for analysis of impact pile driving, but it has some limitations. These are mainly due to uncertainties in quantifying some of the required inputs, such as actual hammer performance and soil parameters.

Types Wave Propagation Pile Testing

There are different types of Wave Propagation pile testing; three of these tests are covered in this method of statement:

1. High Strain Dynamic Testing.
2. Low Strain Pile Integrity Testing.
3. Cross Hole Sonic Test.

1. High Strain Dynamic Test

i. General

High **S**tain **D**ynamic **L**oad **T**esting (**HSDLT**) of piles is a fast and effective method of assessing foundation bearing capacity that requires instrumenting a deep foundation with accelerometers and strain transducers and analyzing data collected by these sensors. The procedure is based on the case method of pile testing and is standardized by **ASTM D4945-08** Standard Test Method for High Strain Dynamic Testing of Piles. It may be performed on driven piles, drilled piles and other cast in place foundations. In addition to bearing capacity, Dynamic Load Testing gives information on resistance distribution (pile resistance and end bearing) and evaluates the shape and integrity of the foundation element. The foundation bearing capacity results obtained with dynamic load tests correlate well with the results of static load tests performed on the same foundation element.

ii. Frequency

The frequency of this test is one pile to represent the entire site including current and future pile installation. Engineer may increase no. of piles (Tests) as required. Typically testing includes 5% to 15% of the total no. of the working piles.

iii. Prerequisite

The static axial capacity of piles typically changes as time elapses after pile installation, possibly increasing (setup) or decreasing (relaxation), depending on the soil or rock properties and the pore water pressure and soil structure disturbance induced by installation. This behavior may affect both driven piles and cast-in-place piles. The Engineer may specify a waiting period between pile installation and High Strain Dynamic Load testing to investigate time effects. The waiting period may range from 3 to 30 days, or longer, based on testing (for example re-driving piles) or prior experience. Also the concrete to be sufficiently hardened. This can be confirmed by the concrete test cube reports.

iv. Method

High-strain dynamic testing is performed by obtaining and analyzing records of pile force and velocity under drop weight or Hammer impacts for evaluations of pile load carrying capacity, structural integrity, and load-movement and pile-soil load transfer relationships. Allow sufficient time for driven and cast-in place deep foundations constructed of concrete to gain adequate structural strength prior to testing.

1. If a permanent casing is not used as a feature to construct the test pile, then a pile top extension, consisting of a thin walled casing or equivalent, shall be used to extend the test pile. Means to insure flat, level, (axial to test pile) and solid concrete pile top. Concrete should be level with, and slightly above the casing. If the top of the test pile is below grade, then remove surrounding soil so as to completely expose a test area as described above. Windows on at least two opposite sides of the test pile may have to be cut off in the steel casing to reach the concrete. (Not Applicable for a pre-cast pile or steel Pipe Pile).

2. In cases where casing is not present, smooth (by grinding) areas around the pile circumference such that proper sensor attachment can be accomplished.

3. Sensors (at least 2 nos.) shall be attached to the exposed concrete or steel casing in a secure manner as to prevent slippage under impact.

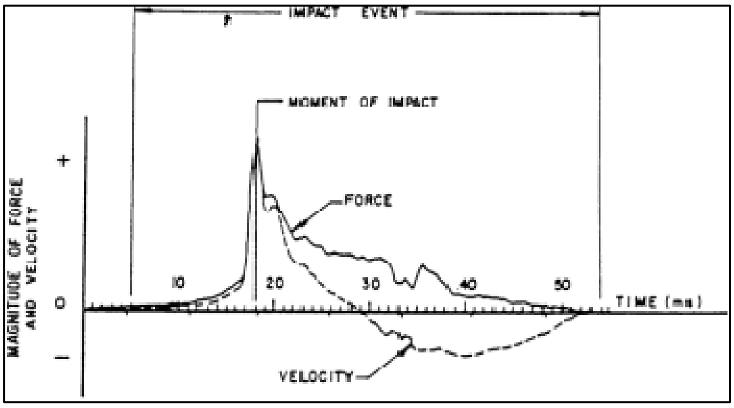
4. For concrete piles or concrete filled pipe piles, place a pile cushion made of plywood or other material with similar stiffness on top of the pile. For concrete filled pipe piles, the concrete must completely fill the pile top so that the impact is transferred through the pile cushion to the concrete.

5. Dynamic tests performed during the initial installation of a driven pile typically monitor the performance of the impact device, the driving stresses in the pile, the pile integrity, and relative changes in capacity. If the test results are used for static capacity computations, then dynamic measurements should (also) be performed during restrikes of the deep foundation, after waiting a period of time following the initial installation sufficient to allow pore water pressure and soil strength changes to occur.

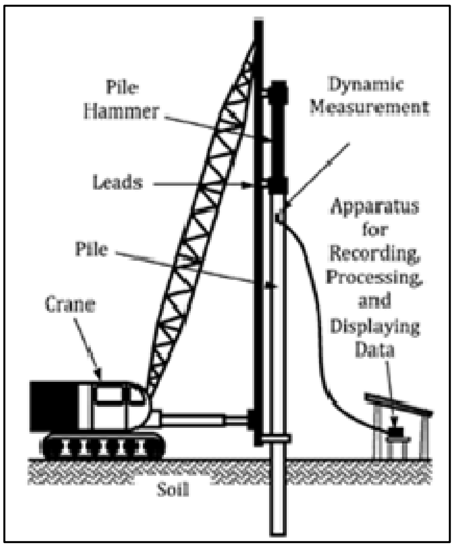
6. A drop weight of approximately two percent (2%) of the anticipated test pile capacity, (one percent may be sufficient for piles with rock sockets); higher percentages are helpful when practical and when available or specialized Diesel/Hydraulic Hammer can be used for pre-cast piles. The impacting surface of the drop weight should have an area between 70 and 130% of the test pile top area. The shape of the ram weight should be as regular as possible (square, round, hexagonal, etc.).A top cushion consisting of new sheets of plywood with total thickness between (50 to 150 mm.) shall be used to absorb the hammer impact.

7. At least two (2) hammer impacts should be applied to the top of the pile. First drop height should be minimal to allow the Testing Engineer to assess the testing equipment, the impact system and the stresses on the foundation. Subsequent impacts can then be applied by utilizing sequentially higher drop heights until either stresses in the foundation are excessive or the pile permanent set for the applied impact exceeds 2.5 mm.

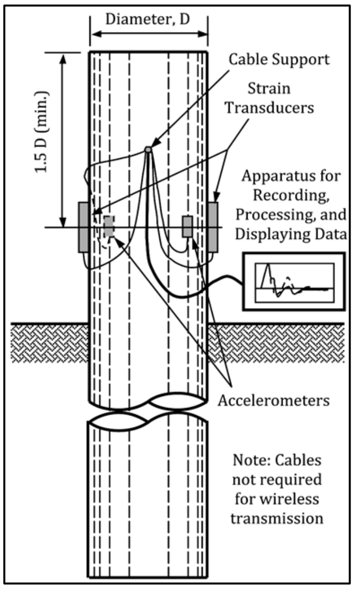
8. Based on the measurements from strain or force, and acceleration, velocity, or displacement transducers, this test method obtains the force and velocity induced in a pile during an axial impact. The Engineer may analyze the acquired data using engineering principles, CAPWAP and judgment to evaluate the integrity of the pile, the performance of the impact system, and the maximum compressive and tensile stresses occurring in the pile and after assessing the resulting dynamic soil response along the side and bottom of the pile, the Engineer may analyze the results of a high-strain dynamic test to estimate the ultimate axial static compression capacity.



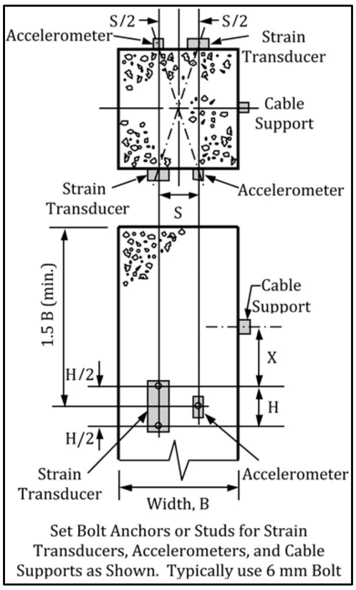
Typical Force and Velocity Traces Generated by the Apparatus for Obtaining Dynamic Measurements



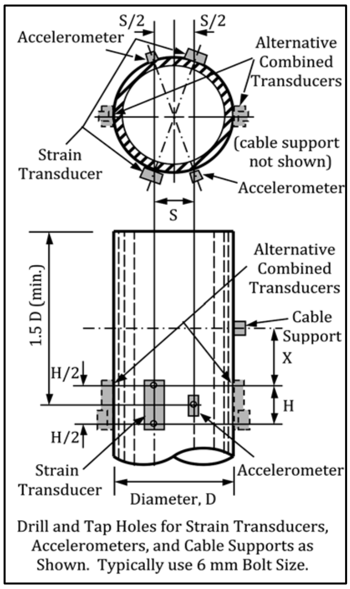
Typical Arrangement for High-Strain Dynamic Testing of a Deep Foundation



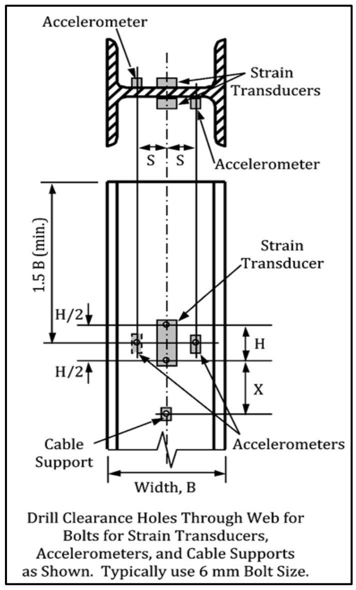
Schematic Diagram of Apparatus for Dynamic Monitoring of Deep Foundations



Typical Arrangement for Attaching Transducers to Concrete Piles



Typical Arrangement for Attaching Transducers to Pipe Piles



Typical Arrangement for Attaching Transducers to H-Piles

2. Low Stain Integrity Test

i. General

Low **S**train **P**ile **I**ntegrity **T**est (**LSPIT**) is echo or seismic method of assessing the integrity of piles has been used since the 1970's to check the integrity of piled foundations and is standardized by ASTM D5882-07 Standard Test Method for Low Strain Integrity Testing of Piles. The system measures the velocity response of a pile to a force input generated by a small hammer. The system is rapid in operation and can be used to check the depth of both pre-cast and cast-in-situ piles. The possible causes of intermediate responses can also be assessed.

ii. Frequency

The frequency of this test is one pile to represent the entire site including current and future pile installation. Engineer may increase no. of piles (Tests) as required. Typically testing includes 100% of the total no. of the working piles

iii. Prerequisite

For cast-in-place concrete piles or concrete filled pipe piles, perform the integrity testing no sooner than 7 days after casting or after concrete strength achieves at least 75 % of its design strength, whichever occurs earlier. Ensure that the pile head surface is accessible, above water, and clean of loose concrete, soil or other foreign materials resulting from construction. If the pile head is contaminated, remove a sufficient pile section to reach sound concrete. Because proper pile top preparation is critical to the successful application of this method, if necessary, prepare small areas by a hand grinder to provide a smooth surface for motion sensor attachment and impact.

iv. Method

The accelerometer must be firmly affixed to the pile top in order to measure the high-frequency motion of that surface during impact and reflection. For best results, the accelerometer should be bonded to the pile top. Petroleum jelly works nicely in cold weather. Other adhesive materials such as plastic clay or bowl sealer wax can also be used.

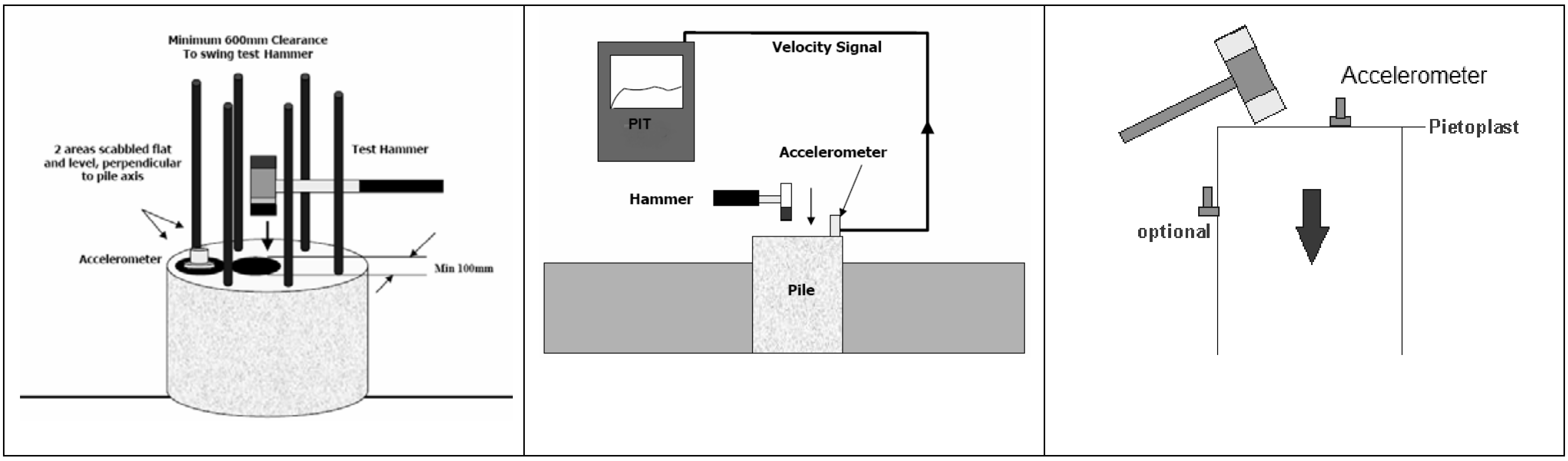
1. The motion sensor should be placed at or near the pile head using a suitable, or temporary, thin layer of bonding material (that is, wax, Vaseline, putty etc.) so that it is assured that it correctly measures the axial pile motion (transducer axis of sensitivity aligned with the pile axis).

2. The motion sensor is placed generally near the center of the pile. Additional locations should be considered for piles with diameters greater than 500 mm.

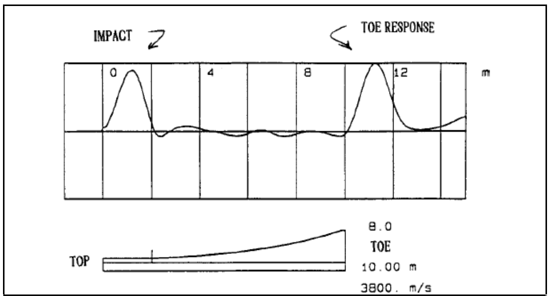
3. The low strain impact should be applied to the pile head within a distance of 300 mm from the motion sensor. If the pile head is not accessible, as when already integral with the structure, the sensor(s) may be attached to the side of the pile.

4. The signals from the motion sensors shall be conveyed to the Pile Integrity Tester (PIT) for recording, reducing, and displaying data as a function of time. The PIT includes a graphic display of velocity, and a data storage capability for retrieving records for further analysis.

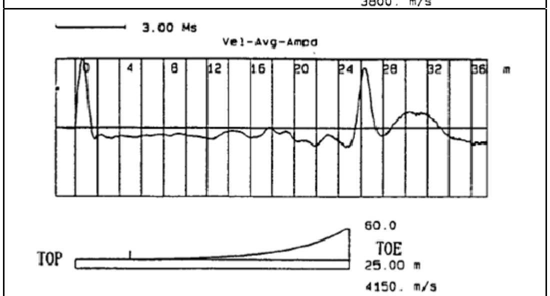
5. Record the measurements from several impacts. Average the suitable records of at least three impacts and apply necessary amplification to the averaged record. The records from the individual impacts or the averaged record, or both, should then be. The averaged, amplified record then can be evaluated for integrity.



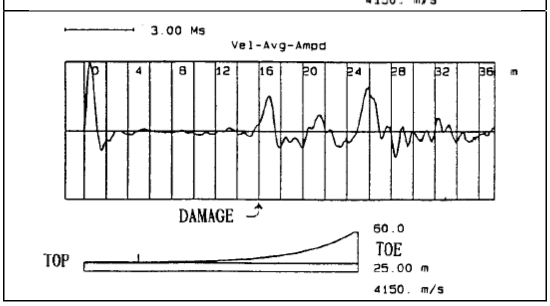
Schematic Diagram of Apparatus for Pile Integrity Tester (PIT)



Typical Velocity Traces for the Pulse Echo Method Generated by the PIT for Obtaining Dynamic Measurements (note the orientation of the input pulse is shown as positive in this standard; orientation could also be shown negative)



Typical Velocity Record Indicating Pile of Generally Uniform Nature (Gradual Impedance Changes or Soil Friction) (note the orientation of the input pulse is shown as positive in this standard; orientation could also be shown negative)



Typical Velocity Record Indicating Major Changes in Impedance (Severe Damage or a Cracked Pile (note the orientation of the input pulse is shown as positive in this standard; orientation could also be shown negative))

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3. Cross Hole Sonic Test

i. General

Cross-hole **S**onic **L**ogging (**CSL**) is a NDT method which involves ultrasonic signal transmission through the pile between two parallel water filled access tubes. The access tubes are often tied to the steel cage and cast permanently into the pile. The total number of access tubes typically depends on the diameter of the pile. A transmitter probe and a receiver probe are lowered to the bottom of the pile in separate access tubes. Measurements of the signal transmission are collected approximately every 5 cm as the probes are raised to the top of the pile. The cables attached to the probes are pulled through calibrated encoder wheels which can accurately determine the depth of the probe during testing. A collection of measurements from one access tube to another are called a profile. Profiles are collected from all combinations of access tubes. The test method is described in ASTM D6760-08.

ii. Frequency

The frequency of this test is one pile to represent the entire site including current and future pile installation. Engineer may increase no. of piles (Tests) as required. Typically testing includes 50% - 100% of the total no. of the working piles.

iii. Prerequisite

The access ducts shall be supplied and installed during construction by or in cooperation with the contractor of the deep foundation element to be tested. The total number of installed access ducts in the deep foundation element should be chosen consistent with good coverage of the cross section. As a guide, the number of access ducts is often selected as one duct for every 0.25 to 0.30 m of deep foundation element diameter, spaced equally around the circumference. A minimum of three access ducts is preferred for cross-hole testing. Single access tubes of PVC or equivalent other material with low wave speed is acceptable for single hole testing of small diameter deep foundation elements.

iv. Method

The actual speed of sound wave propagation in concrete is dependent on the concrete material properties, geometry of the element and wavelength of the sound waves. When ultrasonic frequencies (for example, >20 000 Hz) are generated, Pressure (P) waves and Shear (S) waves travel though the concrete. Because S waves are relatively slow, they are of no further interest in this method. In good quality concrete the P-wave speed would typically range between 3600 to 4400 m/s. Poor quality concrete containing defects (for example, soil inclusion, gravel, water, drilling mud, bentonite, voids, contaminated concrete, or excessive segregation of the constituent particles) has a comparatively lower P-wave speed. By measuring the transit time of an ultrasonic P-wave signal between an ultrasonic transmitter and receiver in two parallel water filled access ducts cast into the concrete during construction and spaced at a known distance apart, such anomalies may be detected.

1. The access tubes shall be filled with water and straight and free from internal obstructions. The exterior tube surface shall be free from contamination (for example, oil, dirt, loose rust, mill scale, etc.), and for plastic tubes the surface shall be fully roughened by abrasion prior to installation, to ensure a good bond between the tube surface and the surrounding concrete. The ends of the tubes shall be undamaged and suitably prepared for the end caps and coupling system adopted. The access tubes shall be close-ended at the bottom and fitted with removable end caps at the top to prevent entry of concrete or foreign objects, which could block the tubes prior to testing operations. If extension of the access tubes is necessary due to long tube lengths, access tube couplings shall be used which prevent slurry or grout ingress during construction. Butt welding for steel tube couplings shall not be permitted. For coupling plastic tubes, threaded or glued plastic couplings shall be used. Wrapping the joints with tape or other compounds is strictly forbidden.

2. The tests shall be performed no sooner than 3 to 7 days after casting depending on concrete strength and shaft diameter (larger diameter shafts may take closer to 7 days). In the case of plastic access tubes, testing should be completed as soon as practical to prevent loss of data caused by de-bonding of the concrete from the tube.

3. The access ducts shall be exposed and the protective top caps removed. Preferably, use a weighted measuring tape to measure and record the length of each access duct to the nearest 10 mm. If the access duct is blocked, record the depth of the blockage from the access duct top. The access ducts shall be filled to the top with clean water.

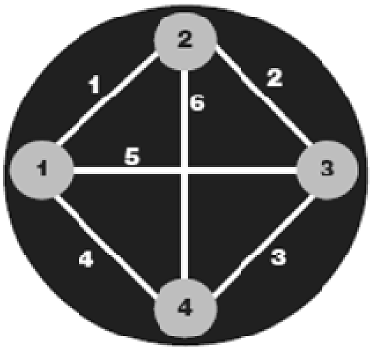
4. Assign a systematic reference label to each access duct and prepare a reference sketch of the access duct layout using the magnetic compass or a site plan diagram. The as-built details of the access duct layout shall be recorded including measuring the center-to center separations of the exposed access ducts to the nearest 10 mm using a measuring tape and measuring the access duct length exposed above the concrete, if any, to the nearest 100 mm.

5. Carefully lower the probes down to the bottom of the access ducts, always keeping them at approximately the same level, until one probe reaches the bottom of the duct or encounters an obstruction (for example, because one access duct is shorter, bent or blocked). Set the depth location to the bottom of the tubes, if necessary. Raise the probes from the tube bottom to a portion of the deep foundation element with good quality concrete. If required by the test system manufacturer, to ensure that the distance between probes is minimized, the relative level of the probes should be adjusted until the time of first arrival of the signal is minimized. Temporarily secure the cables at that level with the cables remaining in equal tension.

6. For Single Hole Sonic Test, The transmitter and receiver probes shall be fixed to each other at a preset vertical separation (for example, typically 600 mm). The vertical separation may be increased to scan a larger radius around the access duct. This will, however, reduce the measured profile length and the detection resolution. Place the probe cable pulley guide into the single access duct (PVC or equivalent duct required). Insert the transmitter and receiver probes into this access duct ensuring that the cables are engaged over the cable pulley guide fixed at the access duct top.

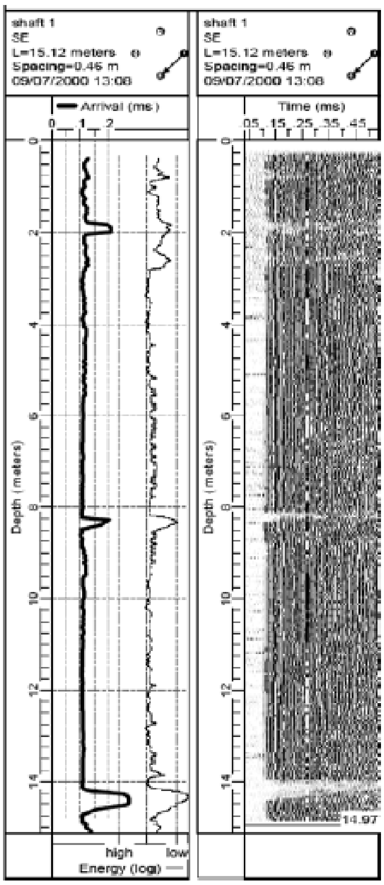
7. Begin recording the ultrasonic pulses as the probes are raised. Lift both probes by steadily pulling the probe cables simultaneously at a speed of ascent slow enough to capture one ultrasonic pulse for each depth interval specified. If an ultrasonic pulse is not obtained for any depth interval, then the probes shall be lowered past that depth and the test repeated until all depth intervals have an associated ultrasonic pulse. Data collection in some systems may proceed from the top down, or during both downward and upward probe travel. In some cases it is advantageous to place the probes at different levels during pulling. The differences can be at either fixed or variable distances depending on the application.

8. The results of the analysis shall include the time of first arrival of the ultrasonic pulses (or calculated wave speed) and the relative energy or amplitude plotted relative to the deep foundation element depth to quantify the extent and location of any apparent anomaly. Energy or amplitude are presented on a log scale, and attenuation of the relative signal strength assessed from the log scale or presented in dB.

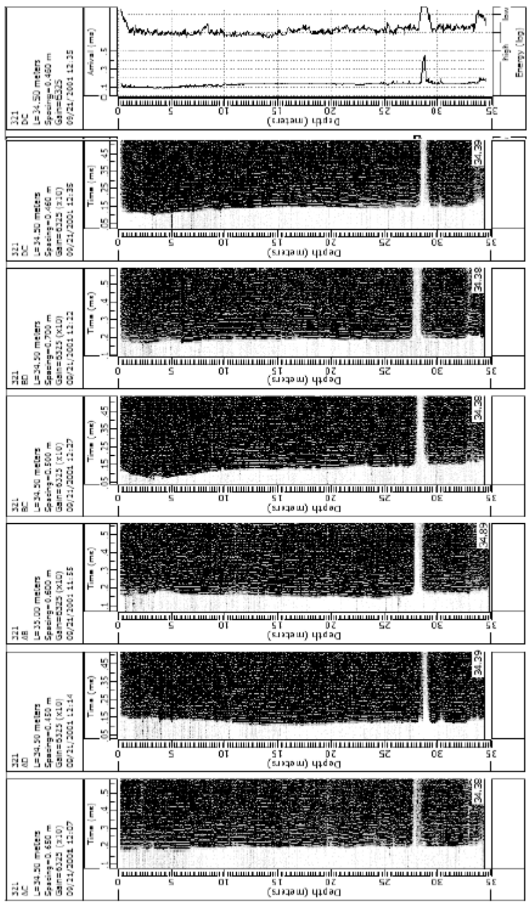


Typical Access Duct Configurations

Test Arrangement for Cross-hole Sonic Logging CSL and Single-hole Sonic Logging SSL



Typical Ultrasonic Profile



Pile with Full Layer Defect

SOFTWARE ANALYSIS

I. CAPWAP

CAPWAP (**CA**se **P**ile **W**ave **A**nalysis **P**rogram) is a software program that estimates total bearing capacity of a pile or shaft, as well as resistance distribution along the shaft and at the toe. The program takes as input the force and velocity data obtained with a Pile Driving Analyzer® (PDA).It is essential to post process PDA data with CAPWAP for at least one foundation element per job. CAPWAP completes the Dynamic Load Testing procedure and simulates a Static Load Test. CAPWAP 2006 has improved features for the analysis of drilled shafts and auger cast-in-place (CFA) piles. The program includes a completely automated mode as well as adjustable parameters with which the user systematically improves the calculated results. CAPWAP works in English, Metric or SI units, and features a comprehensive help feature. The CAPWAP manual introduces the user to the wave equation theory and signal matching procedure on which the program is based.

CAPWAP calculates:

- Static shaft resistance, magnitude and distribution.
- Static end bearing.
- Stresses at any point along the shaft.
- Energy transferred from the ram to the foundation.

From force and velocity data measured by the Pile Driving Analyzer® PDA on a foundation impacted by a ram. Based on these results, CAPWAP simulates a static load test and predicts the instantaneous load settlement behavior of the tested foundation. CAPWAP 2006 has an improved mathematical model that enhances the analysis of drilled shafts and augered cast-in-place piles. Numerous automatic search and help functions make CAPWAP an efficient and reliable analysis tool.

TYPICAL CAPWAP ANALYSIS

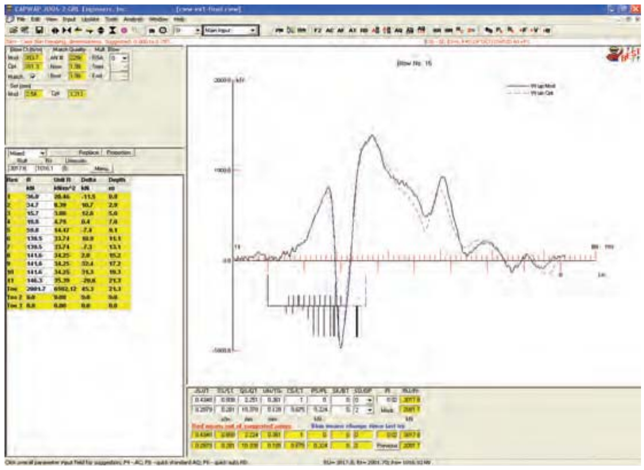
Forces and velocities measured at the top of a foundation during ram impact are related (complementary) quantities; foundation characteristics and soil resistance parameters govern this relationship. The basic CAPWAP procedure uses this fact and consists of the following steps:

1. Retrieve force and velocity data from the Pile Driving Analyzer.
2. Setup pile model.
3. Assume soil resistance parameters.
4. Perform analysis using one of the measured quantities as an input and calculate the complementary quantity.
5. Compare measured with computed quantity.
6. If match is not satisfactory, adjust soil parameters such as resistance, quake and damping and go to step 4.
7. Output soil model, satisfactory match and simulated static test.

HELP FEATURES

CAPWAP guides the user to properly adjust the large number of variables that affect the signal matching process. Arriving at bearing capacity results is an efficient and rewarding process thanks to:

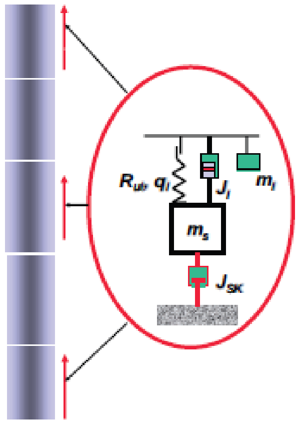
- Automated signal matching option (AC)
- Best match for individual or groups of variables (AQ)
- Automatic resistance distribution (AF)
- Automatic toe parameters check (AT)
- Static resistance – damping exchange (RD)
- Extensive expert help system
- Background manual



CAPWAP Analysis Screen

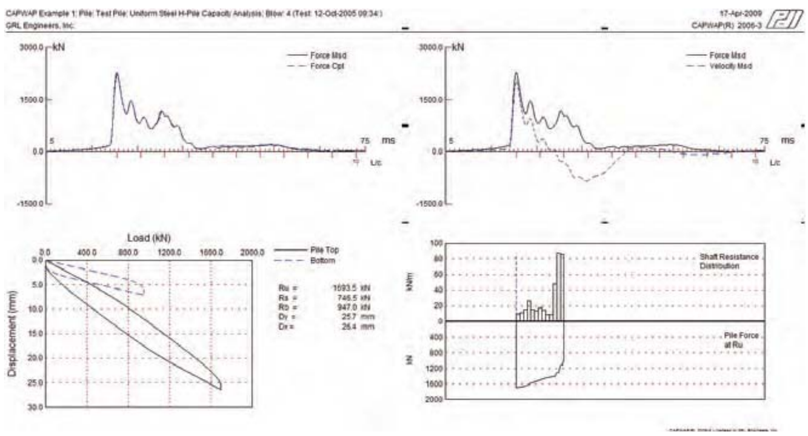
THE CAPWAP PILE AND SOIL MODEL

CAPWAP is a signal matching program with an extended, Smith-type soil and continuous pile model. CAPWAP calculations are based on one-dimensional wave propagation theory. Calculations can be performed in English, SI or Metric units. In its default mode, CAPWAP models the deep foundation as a series of 1 m long uniform sections with multiple elastic properties. Pile damping, splices, non-uniformities and multiple pile or shaft materials may also be modeled. The soil resistance is typically lumped into individual resistance forces at 2 m intervals with elasto-plastic static, linearly viscous and mass related dynamic properties. Radiation damping is represented by an additional mass and dashpot. The user has the option of using individual toe resistance parameters such as a plug mass, a resistance gap and a true Smith damping approach.



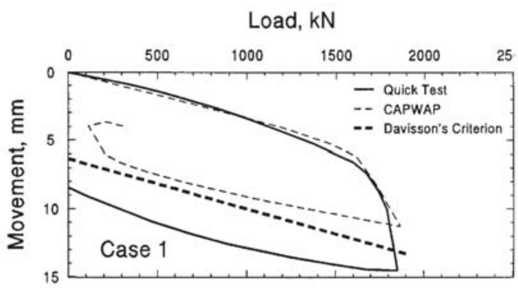
OUTPUT

- Simulated static test.
- Resistance distribution.
- Forces and stresses along the shaft.
- Shaft and toe damping and quake.
- Measured and computed forces and velocities.
- Maxima of displacement and velocity.
- Transferred energy.
- CASE Method results.



CORRELATIONS

Correlations between Load-Set Curves from static load test and from CAPWAP simulated tests on a variety of soils and types of foundations have been extensively proven.



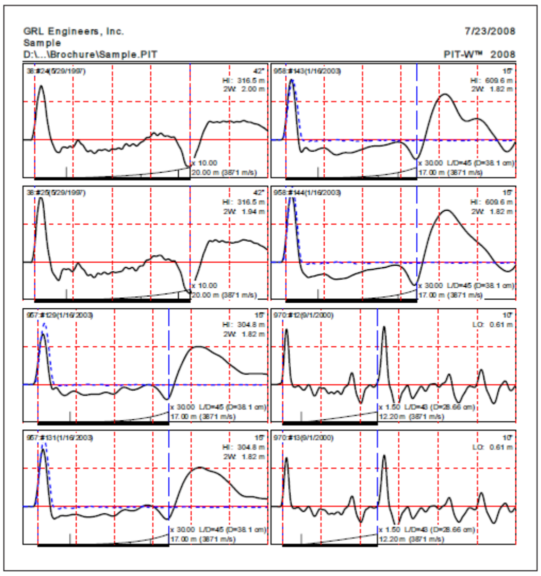
II. Pit-W

Pit-W is software for In-Depth Analysis of Data Collected with the Pile Integrity Tester PIT-W Professional maximizes the information you can extract from data collected with the Pile Integrity Tester (PIT). PIT-W Pro is particularly useful for:

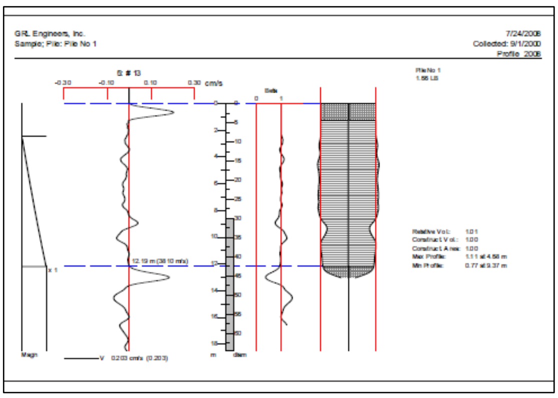
- Comparing records from several piles on the same site.
- Analyzing data from foundations of existing structures.
- Assessing unknown foundation length.
- Evaluating the severity and location of anomalies along the shaft.

PIT-W Advanced Features:

- Profile Analysis - generates pile impedance versus depth plot to help estimate the shape of the foundation
- ß-Analysis - quantifies impedance changes to help assess the severity of defects
- Multiple Column Plot - generates user customized summary sheets for easy record comparison.



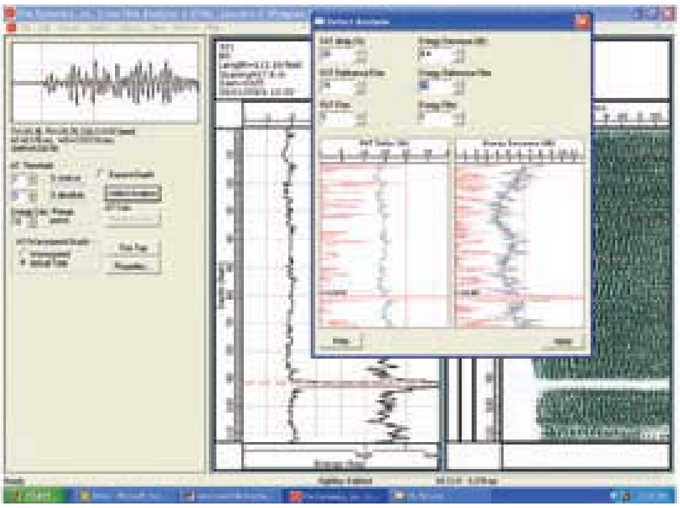
Multiple Columns



Profile Analysis

III. CHA-W

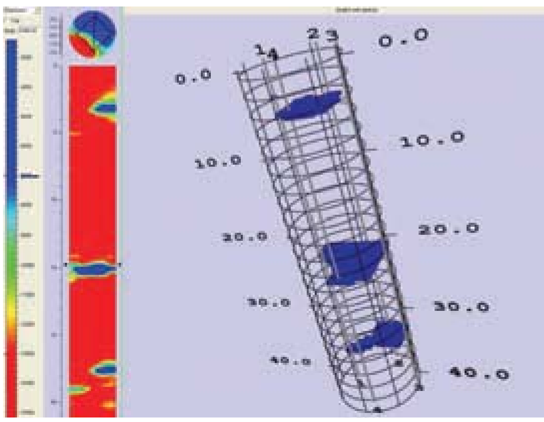
DATA PROCESSING SOFTWARE CHA-W Performs data quality checks. Provides powerful tools for data analysis:



- Edge Finder for First Arrival Time detection.
- Defect Analysis for easy defect identification.
- Two methods of signal strength evaluation (energy or amplitude).

Outputs user customized graphs and tables:

- Sonic Map - Signal strength versus time and depth in traditional waterfall diagram.
- First Arrival Time - Signal travel time from transmitter to receiver, versus depth.
- Wave-speed Plot - Wave-speed (an indicator of concrete strength) versus depth.
- Wave–speed Table - Wave-speeds, means and standard deviations.
- Energy or Amplitude Plot - Signal strength versus depth.
- Defect location graphically (horizontal red line) and in table format.

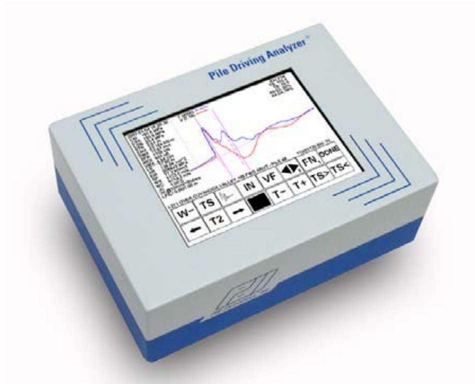


TOMOSONIC

Optical tomography software produces 2-D and 3-D color coded images that help visualize local defects. Views include horizontal and vertical slices and a three dimensional representation of the shaft.

TESTING APPARATUS

Pile Driving Analyzer® (PDA) Model PAX



For Dynamic Load Testing and Dynamic Pile Monitoring, The Pile Driving Analyzer (PDA) acquires data from accelerometers and strain transducers attached to a pile or shaft. The tests require the impact of a pile driving hammer or, if that is not available, of a suitable drop weight.

Dynamic Load Test

- Results: Bearing capacity, structural integrity assessment
- PDA data analyzed with the CAPWAP® software
- Excellent correlation with static load tests
- Performed on drilled Piles, continuous flight auger, cast-in-situ or driven piles on a restrike.

Dynamic Pile Monitoring

- Capacity at the time of testing, driving hammer performance, driving stress, pile integrity.
- Performed during driving.
- Helps establish the Driving Criterion.
- Contributes to safe and economical production pile installation

Strain and Acceleration Sensors

For the Pile Driving Analyzer® and Dynamic Load testing. Strain Transducers and Accelerometers manufactured by Pile Dynamics are reliable, convenient to install and remove, and highly durable.

ACCURACY:

PDI sensors collect axially accurate signals at high micro-strain (strain transducers) and “g” (accelerometers) levels.

CALIBRATION:

Calibration sheets are furnished with each sensor.

Pile Dynamics recommends that sensors be recalibrated at least every two years, in accordance with ASTM D-4945.

Pile Integrity Tester: PIT-FV

The Pile Integrity Tester (PIT) performs Low Strain Integrity Testing, also called Sonic Echo or Pulse Echo Testing. The PIT may be used for augered cast-in-place (CFA) piles, drilled shafts, driven concrete piles, concrete filled pipes and timber piles. It detects potentially dangerous defects such as major cracks, necking, soil inclusions or voids and, in some situations, can determine unknown lengths of piles.

PIT-V, which features a larger screen, also reads velocity data from a single (traditional or cabled) accelerometer **PIT-FV** has two data input channels. The first input is the acceleration measured on the pile. The second input may be from a second accelerometer or from an instrumented hammer.

PIT-V AND FV ACCELEROMETERS

Used with the Pile Integrity Tester (PIT)

Available in top or side mount. Attachment by bolt on system (side) or flat base mount (top) with adhesive. Full waterproofing.

ACCURACY:

PDI sensors collect axially accurate signals at high micro-strain (strain transducers) and "g" (accelerometers) levels.

CALIBRATION:

Calibration sheets are furnished with each sensor.

Pile Dynamics recommends that sensors be recalibrated at least every two years, in accordance with ASTM D-5882.

Cross-Hole Analyzer (CHAMP)

For cross-hole and single hole sonic logging The Cross-Hole Analyzer (CHAMP) determines the quality and consistency of the concrete of drilled shafts, slurry walls, bored piles, cast-in-situ piles and other types of concrete foundations. It may be used for cross-hole sonic logging (CSL) of drilled shafts or single hole sonic logging (SSL) of smaller augered cast-in-place piles.

Features

- Small
- Light weight
- Rugged
- Easy touch screen operation
- Color LCD visible even in direct sunlight
- Battery lasts an entire day of normal testing

Sonic Logging Probes

Probes are sturdy: their oil-filled brass shells are pressure tested for water depths up to 300 m. Transmitter probes have an exclusive safety feature, they are powered by a 12 volt source in the CHAMP and transformed to higher voltages within the probe itself. These higher voltages allow testing between access tubes more than 3 m apart. The probes may be fitted with bottom extension weights for deeper shafts and centralizers to position the probes in the center of the tubes.

RESULTS OF TEST

High Strain Dynamic Testing Report

The report for Dynamic Load testing shall include the following information:

General Information

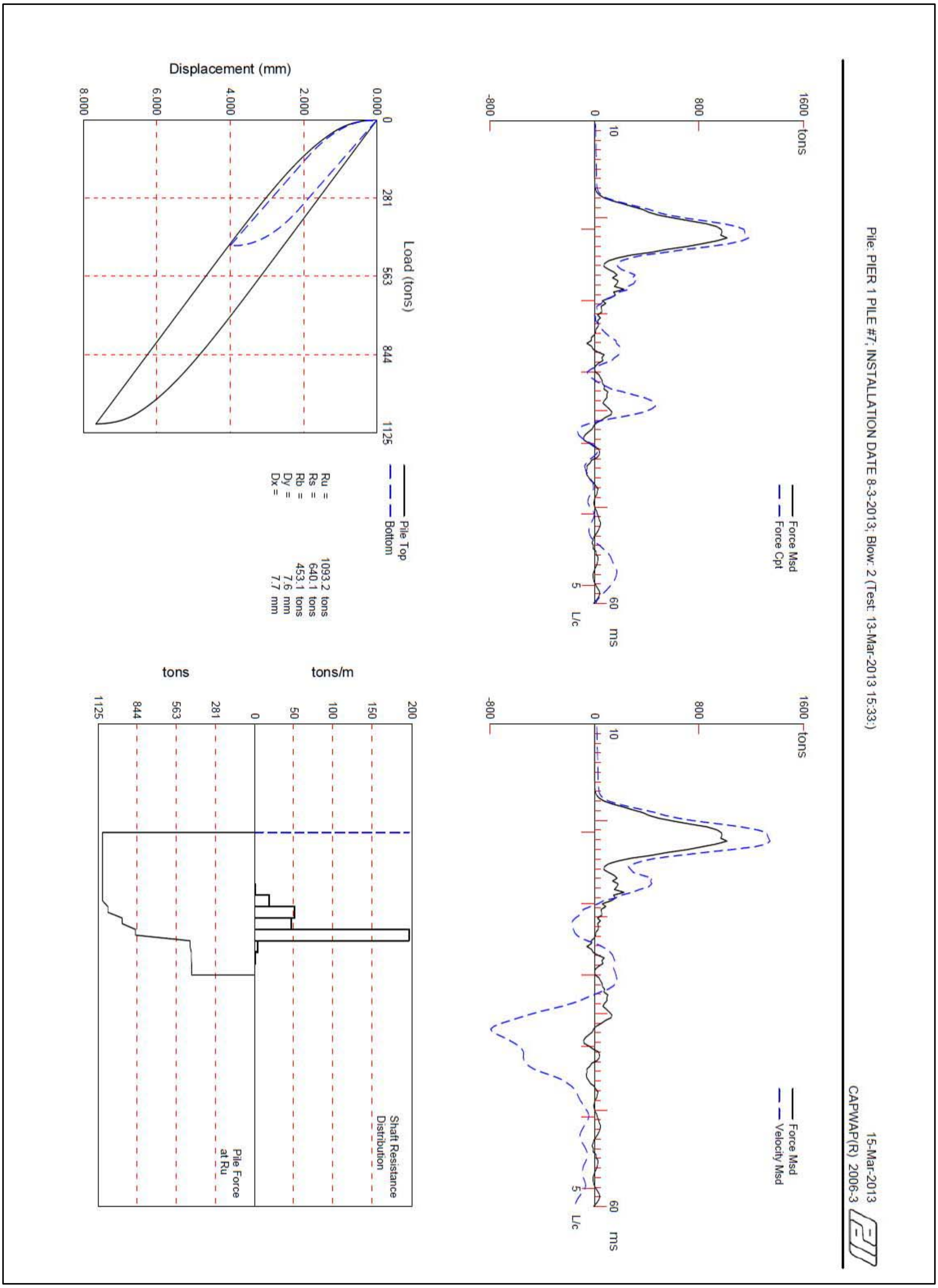
- Project info.
- Client info.
- Pile info (Length, Type, Diameter, Casting/Driving date …etc.).
- Hammer info.
- Comments and recommendations about the pile(s) capacity.
- Equipment Certificates and Calibrations sheets.

Graphical out puts drawing

- Force vs. time curve.
- Velocity vs. time curve.
- Load vs. settlement curve.
- Load Distribution.

Detailed Tables outputs

- CAPWAP Summary
- Soil Model Parameters
- Extrema Table
- Dynamic Resistance Table
- General Summary
- Case Method
- Pile Profile and Pile Model
- Static Load table



Sample of the Graphical output for the Dynamic test report

Pile: PIER 1 PILE #7

Test: 13-Mar-2013 15:33:

CAPWAP(R) 2006-3

مكتب اللقاء الهندسي

لفحص الركائز

CAPWAP SUMMARY RESULTS

Total CAPWAP Capacity: 1093.2; along Shaft 640.1; at Toe 453.1 tons

Soil Sgmnt No.	Dist. Below Gages m	Depth Below Grade m	Ru tons	Force in Pile tons	Sum of Ru tons	Unit Resist. (Depth) tons/m	Unit Resist. (Area) tons/m^2	Smith Damping Factor s/m	Quake mm
				1093.2					
1	3	3	0	1093.2	0	0	0	0	2.47
3	7	7	0	1093.2	0	0	0	0	2.297
5	11	11	0.6	1092.6	0.6	0.3	0.06	0.214	2.194
7	15	15	103	951.4	141.8	51.48	10.93	0.214	2.786
9	19	19	392.2	464.4	628.8	196.08	41.63	0.214	2.978
10	21	21	9	455.5	637.7	4.49	0.95	0.214	3.118
11	23	23	2.3	453.1	640.1	1.17	0.25	0.214	3.167
12	25	25	0	453.1	640.1	0	0	0	3.151
Avg.	Shaft		53.3			25.6	5.44	0.214	2.924
	Toe		453.1				256.55	0.746	3.002

Soil Model Parameters/Extensions		Shaft	Toe
Case Damping Factor		0.084	0.206
Unloading Quake	(% of loading quake)	30	99
Reloading Level	(% of Ru)	100	100
Unloading Level	(% of Ru)	12	
Resistance Gap (included in Toe Quake) (mm)			0.108
Soil Plug Weight	(tons)		2.11

max. Top Comp. Stress = 0.067 tons/cm^2 (T= 22.7 ms, max= 1.048 x Top)

max. Comp. Stress = 0.070 tons/cm^2 (Z= 15.0 m, T= 26.9 ms)

max. Tens. Stress = -0.031 tons/cm^2 (Z= 20.0 m, T= 31.0 ms)

max. Energy (EMX) = 2.62 tonne-m; max. Measured Top Displ. (DMX)= 4.32 mm

EXTREMA TABLE

Pile Sgmnt No.	Dist. Below Gages m	max. Force tons	min. Force tons	max. Comp. Stress tons/cm^2	max. Tens. Stress tons/cm^2	max. Trnsfd. Energy tonne-m	max. Veloc. m/s	max. Displ. mm
1	1	1181.9	-142	0.067	-0.008	2.62	0.7	3.424
4	4	1181	-214.5	0.067	-0.012	2.61	0.7	3.358
8	8	1182.6	-290.6	0.067	-0.016	2.58	0.7	3.163
10	10	1190.2	-349.6	0.067	-0.02	2.56	0.7	3.143
12	12	1208.7	-397.3	0.068	-0.022	2.56	0.7	3.192
16	16	1189.7	-379.5	0.067	-0.021	2.25	0.6	3.215
18	18	1163	-356.9	0.066	-0.02	2.11	0.6	3.157
20	20	938	-542.8	0.053	-0.031	1.59	0.7	3.112
21	21	865.9	-464.5	0.049	-0.026	1.53	0.7	3.123
23	23	708.2	-170	0.04	-0.01	1.38	0.9	3.197
25	25	564.5	-80.1	0.032	-0.005	1.41	0.9	3.167
Absolute	15			0.07				(T = 26.9 ms)
	20				-0.031			(T = 31.0 ms)

Sample (1 of 3) of the detailed table output

Pile: PIER 1 PILE #7

Test: 13-Mar-2013 15:33:

CAPWAP(R) 2006-3

DYNAMIC RESISTANCE TABLE

Soil Sgmnt No.	Dist. Below Gages m	Depth Below Grade m	Ru tons	Damping Rd at Max. Rt tons	Max Rt (Ru+Rd) tons	Depth tons/m	Total Unit R W. Resp. to Area tons/m^2	Smith Damping Factor s/m	Quake mm
1	3	3	0	0	0	0	0	0	2.47
2	5	5	0	0	0	0	0	0	2.373
4	9	9	0	0	0	0	0	0	2.21
5	11	11	0.6	0.1	0.7	0.33	0.07	0.214	2.194
8	17	17	94.8	3.2	98	49	10.4	0.214	3.008
9	19	19	392.2	3.9	396.1	198.04	42.05	0.214	2.978
11	23	23	2.3	0	2.4	1.18	0.25	0.214	3.167
12	25	25	0	0	0	0	0	0	3.151
Avg.	Shaft		53.3	1.2	54.5	26.18	5.56	0.214	2.924
	Toe		453.1	150.3	603.4		341.67	0.746	3.002
	Total				1257.9				

General Summary

Mobilized Soil Resistance	1093	tons
Mobilized Shaft Resistance	640.1	tons
Mobilized Toe Resistance	453.1	tons
Maximum Displacement at Failure	7.562	mm
Maximum Static Top Displacement	7.661	mm
Maximum Compressive Stress	0.07013	tons/cm^2
Maximum Tension Stress	0.03073	tons/cm^2
Maximum Transferred Energy (Measured)	2.616	tonne-m

CASE METHOD

J =	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8
RP	1100.1	980.9	861.6	742.4	623.1	503.9	384.6	265.3	146.1
RX	1118.2	992.2	866.3	742.4	643.1	643.1	643.1	643.1	643.1
RU	1282.5	1181.5	1080.4	979.4	878.4	777.4	676.4	575.3	474.3

RAU = 608.7 (tons); RA2 = 639.1 (tons)

Current CAPWAP Ru = 1093.2 (tons); Corresponding J(RP)= 0.01; J(RX) = 0.02

VMX m/s	TVP ms	VT1*Z tons	FT1 tons	FMX tons	DMX mm	DFN mm	SET mm	EMX tonne-m	QUS tons
0.82	21.55	1331.7	961	1032.7	4.317	0.099	0.1	2.5	1149.7

PILE PROFILE AND PILE MODEL

Depth m	Area cm^2	E-Modulus tons/cm^2	pec. Weigh tons/m^3	Perim. m
0	17662	351.5	2.403	4.71
25	17662	351.5	2.403	4.71
Toe Area	1.766	m^2		

Top Segment Length 1.00 m, Top Impedance 1639.15 tons/m/s

Pile Damping 2.0 %, Time Incr 0.295 ms, Wave Speed 3387.8 m/s, 2L/c 14.8 ms

Sample (2 of 3) of the detailed table output

Pile: PIER 1 PILE #7

Test: 13-Mar-2013 15:33:

CAPWAP(R) 2006-3

STATIC ANALYSIS

Step No.	Top Load tons	Top Disp. mm	Toe Load tons	Toe Disp. mm
0	0	0	0	0
4	27.6	0.156	10	0.066
8	55.3	0.312	19.9	0.132
12	82.9	0.467	29.9	0.198
16	110.5	0.623	39.8	0.264
20	138.1	0.779	49.8	0.33
24	165.8	0.935	59.7	0.396
28	193.4	1.09	69.7	0.462
32	221	1.246	79.7	0.528
36	248.6	1.402	89.6	0.594
40	276.3	1.558	99.6	0.66
44	303.9	1.713	109.5	0.726
48	331.5	1.869	119.5	0.792
52	359.1	2.025	129.5	0.858
56	386.8	2.181	139.4	0.924
60	414.4	2.337	149.4	0.99
64	442	2.492	159.3	1.056
68	469.6	2.648	169.3	1.122
72	497.2	2.804	179.2	1.187
76	524.8	2.959	189.2	1.253
80	552.2	3.115	199.2	1.319
84	579.6	3.27	209.1	1.385
89	613.6	3.464	221.6	1.468
94	647.3	3.656	234	1.55
99	680.5	3.848	246.5	1.633
104	713.3	4.039	258.9	1.715
109	745.5	4.229	271.3	1.798
114	776.9	4.416	283.8	1.88
119	807.1	4.6	296.2	1.963
124	836	4.781	308.7	2.045
129	863.5	4.957	321.1	2.128
135	894.1	5.162	335.3	2.227
148	951.8	5.577	363.4	2.441
155	978.2	5.785	376.9	2.556
162	1000.9	5.981	389.3	2.672
170	1023.4	6.194	402.1	2.804
178	1042.5	6.395	413.4	2.936
187	1059.8	6.607	424.4	3.084
196	1072.6	6.804	433.5	3.233
206	1081.5	7.003	441.5	3.398
217	1087.8	7.21	447.7	3.579
227	1091	7.388	450.9	3.744
233	1091.8	7.49	451.8	3.843
236	1092	7.54	451.9	3.892
237	1093.2	7.562	453.1	3.909

Continue

Step No.	Top Load tons	Top Disp. mm	Toe Load tons	Toe Disp. mm
241	1093.2	7.628	453.1	3.975
243	1093.2	7.661	453.1	4.008
247	1079.4	7.583	448.1	3.975
248	1072.5	7.544	445.7	3.958
252	1044.8	7.388	435.7	3.892
256	1017.2	7.232	425.7	3.826
260	989.6	7.077	415.8	3.76
264	962	6.921	405.8	3.694
268	934.3	6.765	395.9	3.628
272	906.7	6.609	385.9	3.562
276	879.1	6.454	375.9	3.496
280	851.5	6.298	366	3.431
284	823.8	6.142	356	3.365
288	796.2	5.986	346.1	3.299
292	768.6	5.831	336.1	3.233
296	741	5.675	326.2	3.167
300	713.3	5.519	316.2	3.101
304	685.7	5.363	306.2	3.035
308	658.1	5.207	296.3	2.969
312	630.5	5.052	286.3	2.903
316	602.8	4.896	276.4	2.837
320	575.3	4.74	266.4	2.771
324	547.8	4.585	256.5	2.705
328	520.4	4.43	246.5	2.639
333	486.4	4.236	234.1	2.556
338	452.6	4.043	221.6	2.474
343	419.3	3.851	209.2	2.391
348	386.4	3.66	196.7	2.309
353	354.1	3.47	184.3	2.227
358	322.4	3.282	171.8	2.144
363	292	3.097	159.4	2.062
368	262.8	2.916	146.9	1.979
379	204	2.533	120.1	1.798
385	175.5	2.335	106.5	1.699
392	145.4	2.115	91.8	1.583
399	118.6	1.905	78.1	1.468
406	95.4	1.707	65.6	1.352
414	72.4	1.493	52.6	1.22
422	52.9	1.29	41.1	1.089
431	35.1	1.077	29.9	0.94
440	21.8	0.878	20.5	0.792
450	12.4	0.677	12.3	0.627
461	5.9	0.469	5.8	0.445
472	2.2	0.273	2.2	0.264

Sample (3 of 3) of the detailed table output

Certificate of Compliance

Pile Dynamics, Inc. certifies that the

Pile Driving Analyzer®, Model PAX

Serial Number: 4010LA

has been tested and passed all final test procedures on 21-Jan-2013

and complies with the criteria as set forth in ASTM Standard D-4945

Tested by:

Pile Dynamics, Inc.
30725 Aurora Road
Cleveland, Ohio 44139 USA

Certificate of Calibration

Pile Dynamics, Inc. certifies that the

Pile Driving Analyzer®, Model PAX

Serial Number: 4010LA

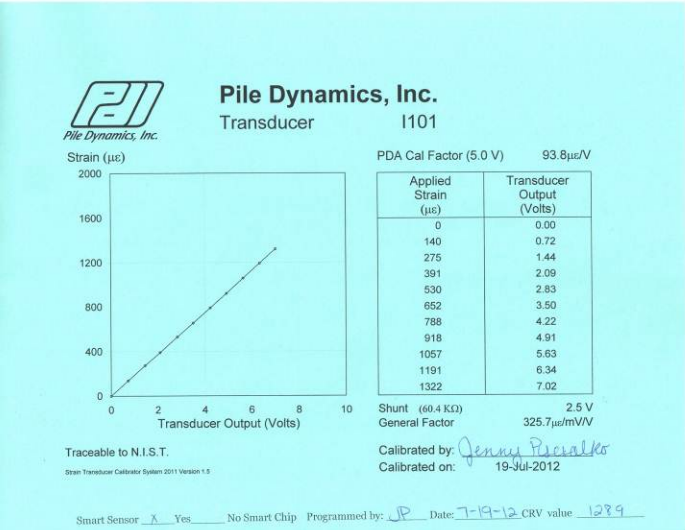
was calibrated on 21-Jan-2013

using a PDA Calibration Box whose output was calibrated with test equipment traceable to NIST.

This certificate is valid for 2 years from above date.

Tested by:

Pile Dynamics, Inc.
30725 Aurora Road
Cleveland, Ohio 44139 USA



PDA Cal Factor (5.0 V) 93.8με/V

Applied Strain (με)	Transducer Output (Volts)
0	0.00
140	0.72
275	1.44
391	2.09
530	2.83
652	3.50
788	4.22
918	4.91
1057	5.63
1191	6.34
1322	7.02

Shunt (60.4 KΩ) 2.5 V

General Factor 325.7με/mV/V

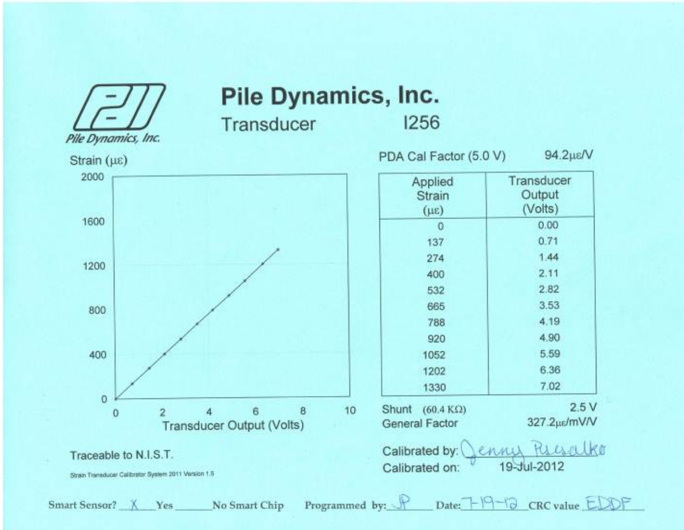
Traceable to N.I.S.T.

Strain Transducer Calibrator System 2011 Version 1.5

Calibrated by: Jenny Piccalko

Calibrated on: 19-Jul-2012

Smart Sensor X Yes ___ No Smart Chip Programmed by: JP Date: 7-19-12 CRV value 1289



PDA Cal Factor (5.0 V) 94.2με/V

Applied Strain (με)	Transducer Output (Volts)
0	0.00
137	0.71
274	1.44
400	2.11
532	2.82
665	3.53
788	4.19
920	4.90
1052	5.59
1202	6.36
1330	7.02

Shunt (60.4 KΩ) 2.5 V

General Factor 327.2με/mV/V

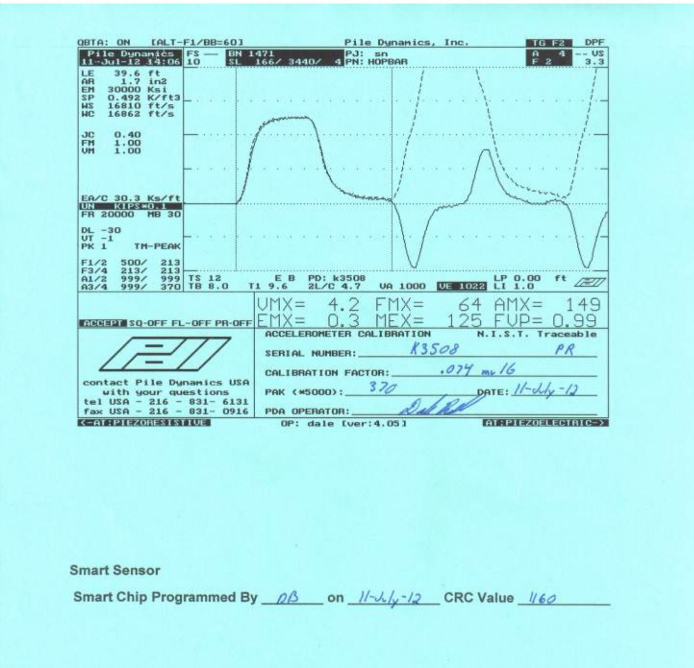
Traceable to N.I.S.T.

Strain Transducer Calibrator System 2011 Version 1.5

Calibrated by: Jenny Piccalko

Calibrated on: 19-Jul-2012

Smart Sensor? X Yes ___ No Smart Chip Programmed by: JP Date: 7-19-12 CRC value EDDF



ACCELEROMETER CALIBRATION N.I.S.T. Traceable

SERIAL NUMBER: K3508 PR

CALIBRATION FACTOR: .074 mv/G

PAK (*5000): 370 DATE: 11-July-12

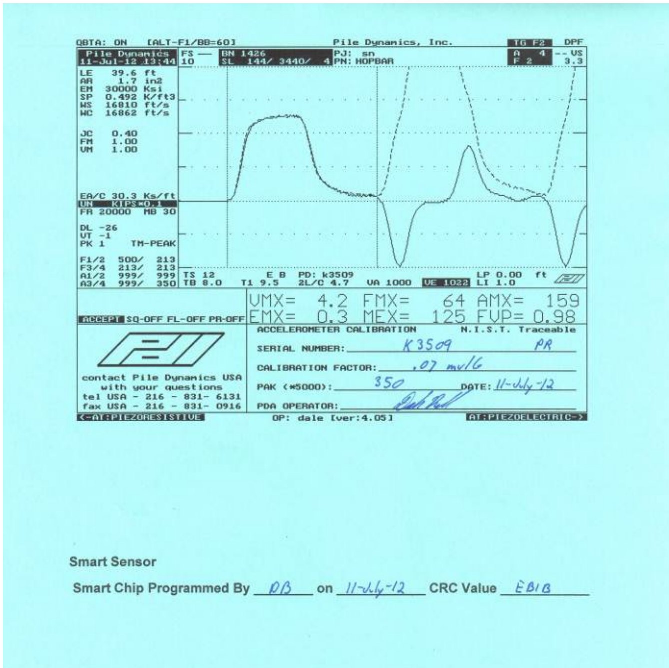
PDA OPERATOR:

contact Pile Dynamics USA with your questions
tel USA - 216 - 831- 6131
fax USA - 216 - 831- 0916

<-AT:PIEZORESISTIVE OP: dale [ver:4.05] AT:PIEZOELECTRIC->

Smart Sensor

Smart Chip Programmed By DB on 11-July-12 CRC Value 1160



ACCELEROMETER CALIBRATION N.I.S.T. Traceable

SERIAL NUMBER: K3509 PR

CALIBRATION FACTOR: .07 mv/G

PAK (*5000): 350 DATE: 11-July-12

PDA OPERATOR:

contact Pile Dynamics USA with your questions
tel USA - 216 - 831- 6131
fax USA - 216 - 831- 0916

<-AT:PIEZORESISTIVE OP: dale [ver:4.05] AT:PIEZOELECTRIC->

Smart Sensor

Smart Chip Programmed By DB on 11-July-12 CRC Value EB1B

Sample of the Certificates and Calibration Sheets

Low Strain Pile Integrity Testing

The report for Pile Integrity Test shall include the following information:

General Information

- Project info.
- Client info.
- Pile info (Length, Type, Diameter, Casting/Driving date …etc.).
- Assessment (Pile Acceptance criteria)
- Equipment Certificates and Calibrations sheets.

Graphical out puts drawing

- Velocity vs. time curve for average impacts for each individual pile.
- Pile profile plot (in case of flaw or damage).

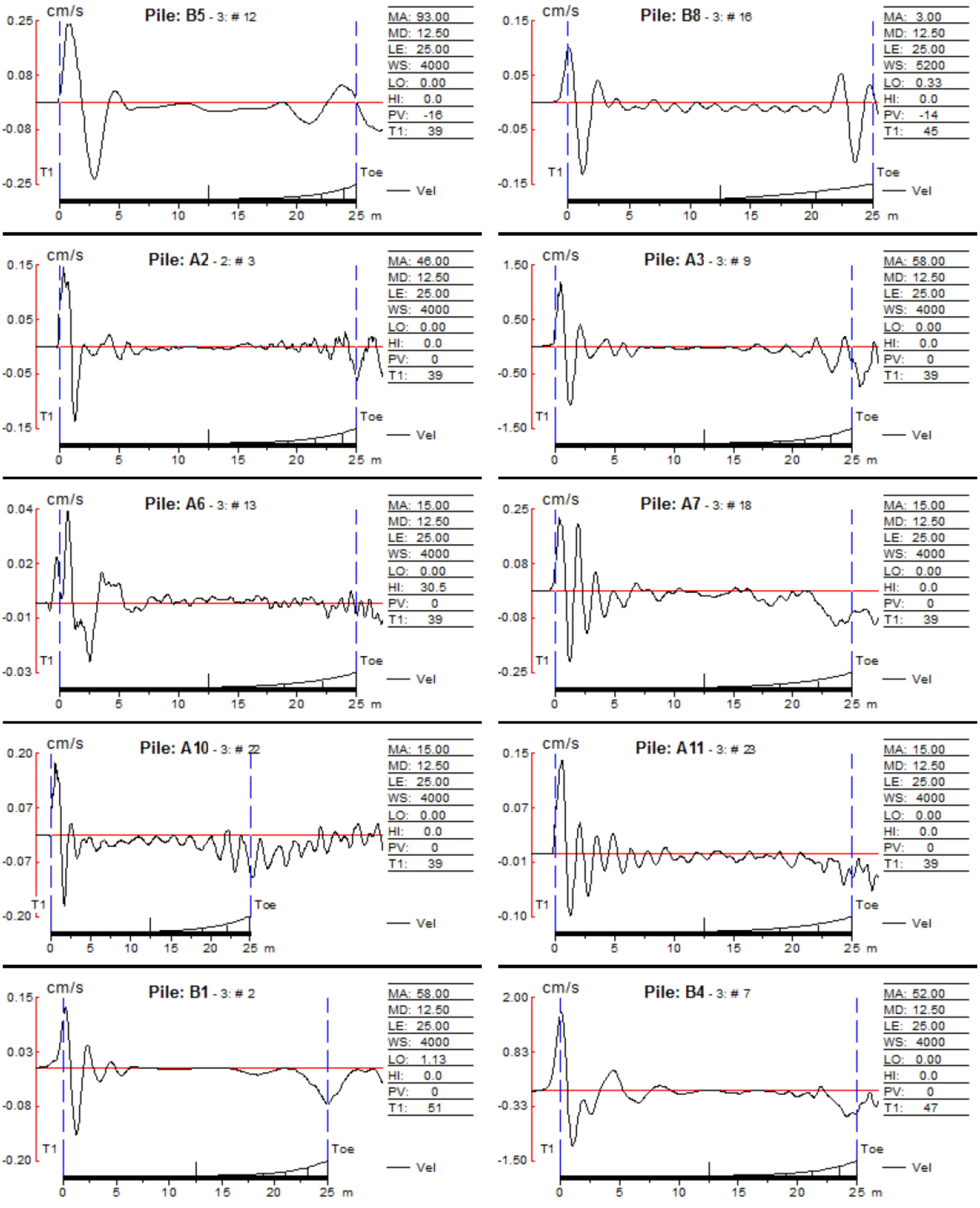
Detailed Tables outputs

- Piles Rating (AA, AB, ABx, PFx or PDx)

Al Liqa'a Bureau for Piling Test

Integrity Test Repot for [redacted] on the railway track ([redacted])

7. Curves



- 3 -

Sample of the Velocity curves

AL-LIQA'A BUREAU FOR PILING TEST | Street 18, Al-Rashan Building, Karadah Kharij
Phone: +964 (0) 7902 377 309
www.lptconsultant.com
Email: info@lptconsultant.com

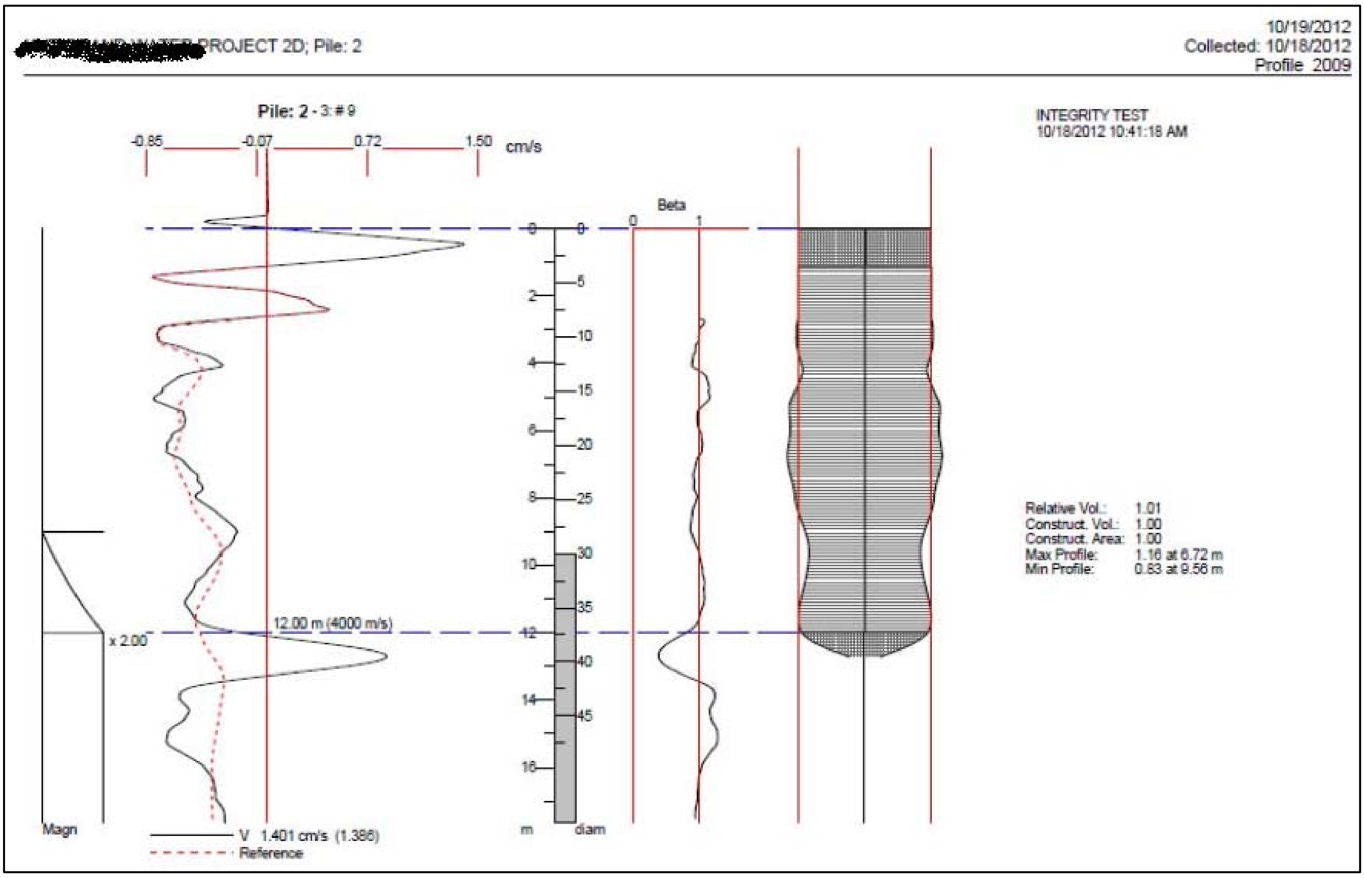
Rating	Piles Name	Comments
AA	090 – 281	Strong and clear toe reflection with no major defect
AB	018 – 088 – 089 – 091 – 093 – 182 – 183 – 277 – 284 – 286 – 287 – 288 – 292 – 294 – 298 – 299 – 301 – 306 – 316 – 318 – 328 – 355 – 358 – 360 – 362 – 369 – 370 – 387 – 388 – 464 – 467 – 474 – 475 – 478 – 483	Toe reflection is not clear , and with no or minor defect
ABx10	468	No major defect till depth of 10M

Summary

AA: 2 Piles
AB: 35 Piles
ABx10 : 1 Piles

Total = 38 Piles

Sample of the Piles Rating Table



Sample of the Pile Profile Plot

Certificate of Compliance

Pile Dynamics, Inc. certifies that the

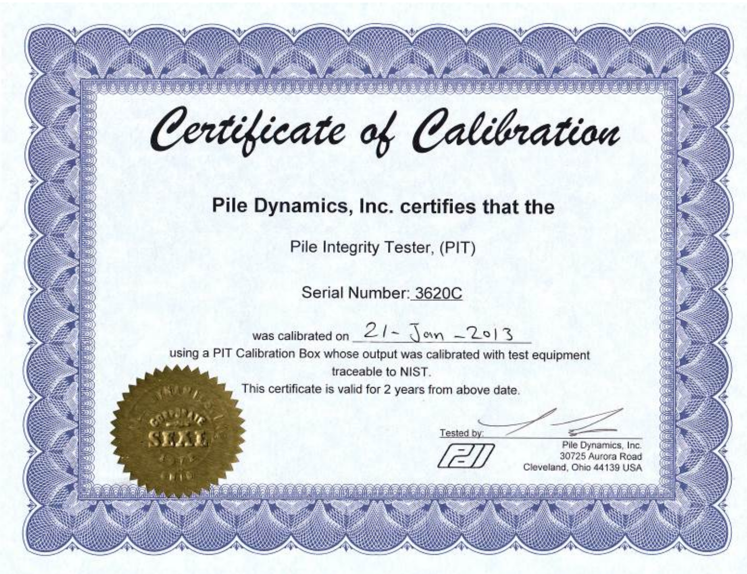
Pile Integrity Tester™ (P.I.T.) Collector

Serial Number: 3620C

has been tested and passed all final test procedures on 21-Jan-2013

and complies with the criteria as set forth in ASTM Standard D-5882

Pile Dynamics, Inc.
30725 Aurora Road
Cleveland, Ohio 44139 USA



Certificate of Calibration

Pile Dynamics, Inc. certifies that the

Pile Integrity Tester, (PIT)

Serial Number: 3620C

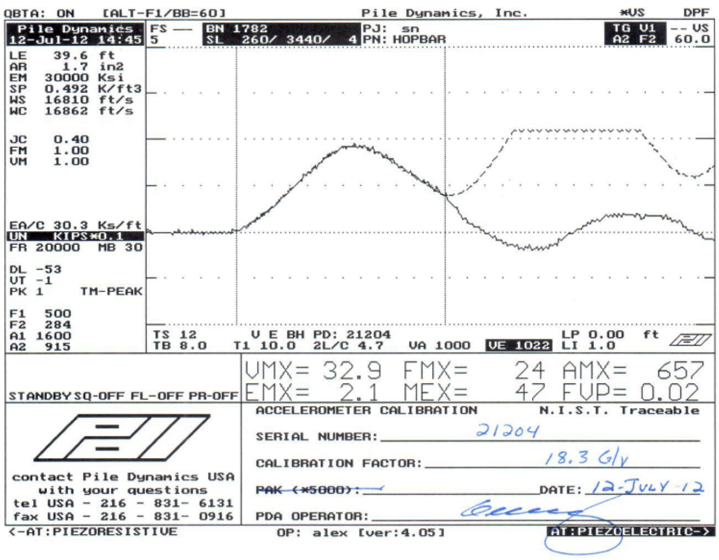
was calibrated on 21-Jan-2013

using a PIT Calibration Box whose output was calibrated with test equipment traceable to NIST.

This certificate is valid for 2 years from above date.

Tested by:

Pile Dynamics, Inc.
30725 Aurora Road
Cleveland, Ohio 44139 USA



Sample of Equipment Certificates and Calibration sheets

Cross Hole Sonic Test

The report for Cross-hole Sonic Test shall include the following information:

General Information

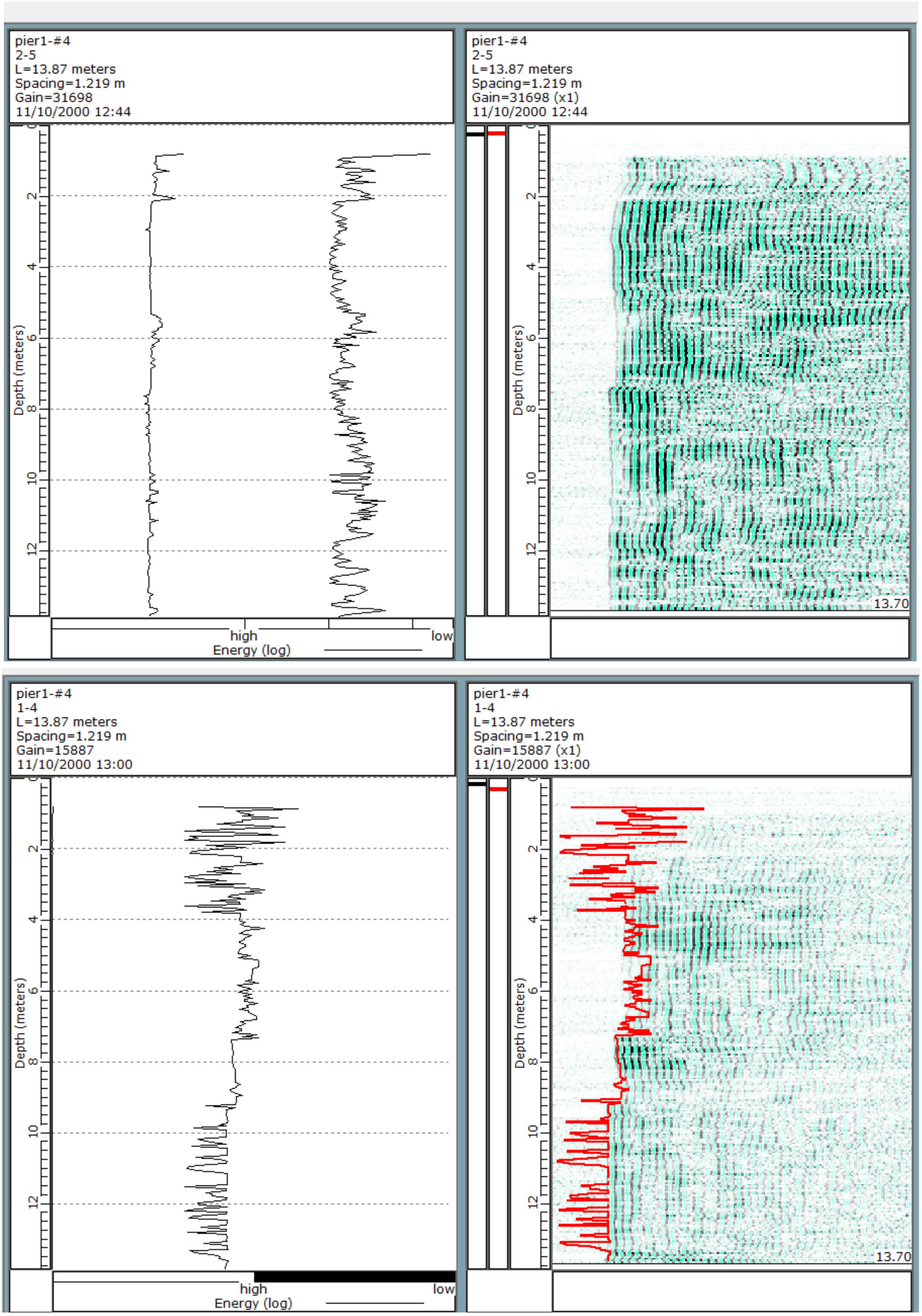
- Project info.
- Client info.
- Pile info (Length, Type, Diameter, Casting date …etc.).
- Comment and Recommendation on each pile condition.

Access Tube Information

- No. of access tube and dimensions.
- Access tube drawings.
- Total no. of used path.

Graphical out puts drawing

- Velocity Log curve, for each access tube combination.



Sample of Velocity plots of 2 Paths

ACCEPTANCE CRITERIA

The acceptance of a Test will be based on the following:

- The pile was installed in accordance with its respective specification.

- All the Project/Client/Pile Information shall be submitted by the Engineer prior to the test.

- The pile was tested in accordance with the test procedures contained in this Method of Statement and according to the corresponding American Standard code:
    - ASTM D4549-08 for Dynamic Load Test
    - ASTM D5882-07 for Pile Integrity Test
    - ASTM D6760-08 for Cross hole Sonic Test

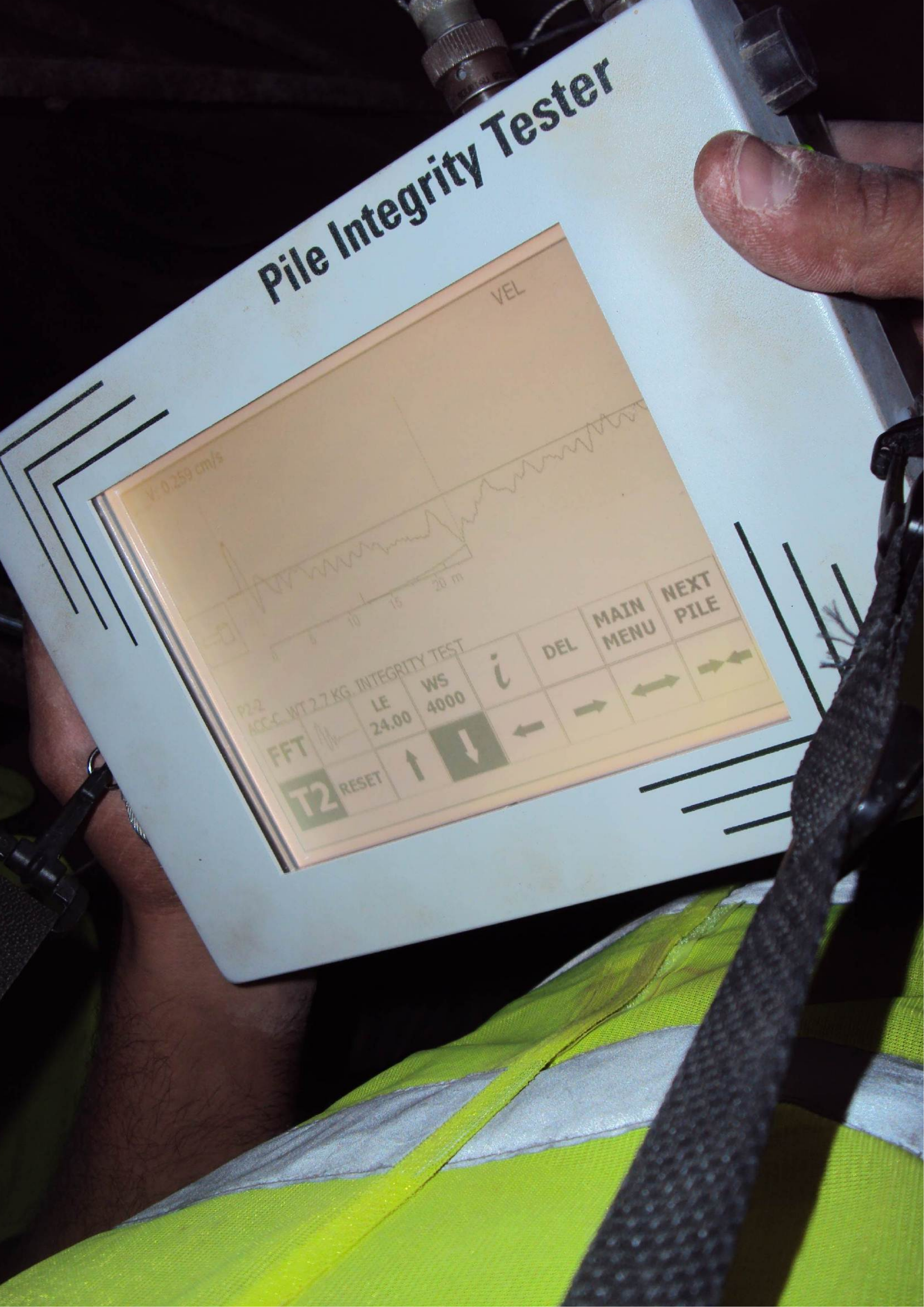
- All field testing and measurements shall be made in the presence of the Engineer.

- The equipment required to be attached to the pile shall be appropriately positioned and fixed to the approval of the Engineer.

- Equipment readings validate that no load or stress was transferred to the Pile exceeding the allowable limits (If such limit was proposed by the Engineer).

- The acceptable test pile meets any other criteria indicated in the contract documents.

- The “Test Report” and equipment certifications and Calibrations have been submitted as outlined in “Test Results”.


Pile Integrity Tester
VEL
V: 0.259 cm/s
20 m
NEXT PILE
MAIN MENU
DEL
i
WS 4000
LE 24.00
P2-2
ACC-C, WT 2.7 KG, INTEGRITY TEST
FFT
T2
RESET

METHOD OF STATEMENT FOR WAVE PROPAGATION PILE TESTING

High Strain Dynamic Test,

Low Strain Integrity Test

&

Cross Hole Sonic Test

According to the American Standards

ASTM D4945-08, ADTM D5882-07 and ASTM D6760-08