METHOD STATEMENT FOR HIGH STRAIN DYNAMIC TESTING (PDA)

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SOIL DYNAMICS

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SOIL DYNAMICS

1 OVERVIEW

High strain dynamic testing is a method of testing deep foundations to obtain information about their capacity and integrity and in some cases to monitor their installation. This method is covered under D4945-12 - Standard Test Method for High-Strain Dynamic Testing of Piles.

High strain dynamic testing encompasses dynamic pile monitoring, applicable only to driven piles, and dynamic load testing, which is applicable to any type of deep foundation.

High strain dynamic testing consists of estimating soil resistance and its distribution from force and velocity measurements obtained near the top of a foundation impacted by a hammer or drop weight. The impact produces a compressive wave that travels down the shaft of the foundation.

A pair of strain transducers obtains the signals necessary to compute force, while measurements from a pair of accelerometers are integrated to yield velocity. These sensors are connected to the Pile Driving Analyzer (PDA) which records, processes and displays data and results. Refer to Appendix A for PDA product details.

2 THEORY

As long as the wave travels in one direction, force and velocity are proportional and related by the expression F = Zv, where:

Z = EA/c is the pile impedance

E is the pile material modulus of elasticity

A is the cross sectional area of the pile

c is the material wave speed at which the wave front travels

The wave assumes an opposite direction (a reflection) when it encounters soil resistance forces along the shaft or at the toe. These reflections travel upward along the shaft and arrive at the pile top at times that are related to their location along the shaft. The sensors near the pile top take measurements that translate what is happening to the traveling waves, and make it possible to estimate soil resistance and its distribution.

The data obtained in this fashion permits the computation of total soil resistance, which includes both static and viscous components. The dynamic component is computed as the product of the pile velocity times the damping factor (a soil parameter related to soil grain size). The static component is the total soil resistance minus the dynamic component.

Dynamic load testing takes a further step in analysing the data and computing static capacity and resistance distribution.

Dynamic pile test carried out during the installation of a driven pile also allows for the computation of the hammer impact energy transferred to the pile, evaluation of compression and tension stresses in the pile. Integrity of the pile can also be examined throughout the installation process.

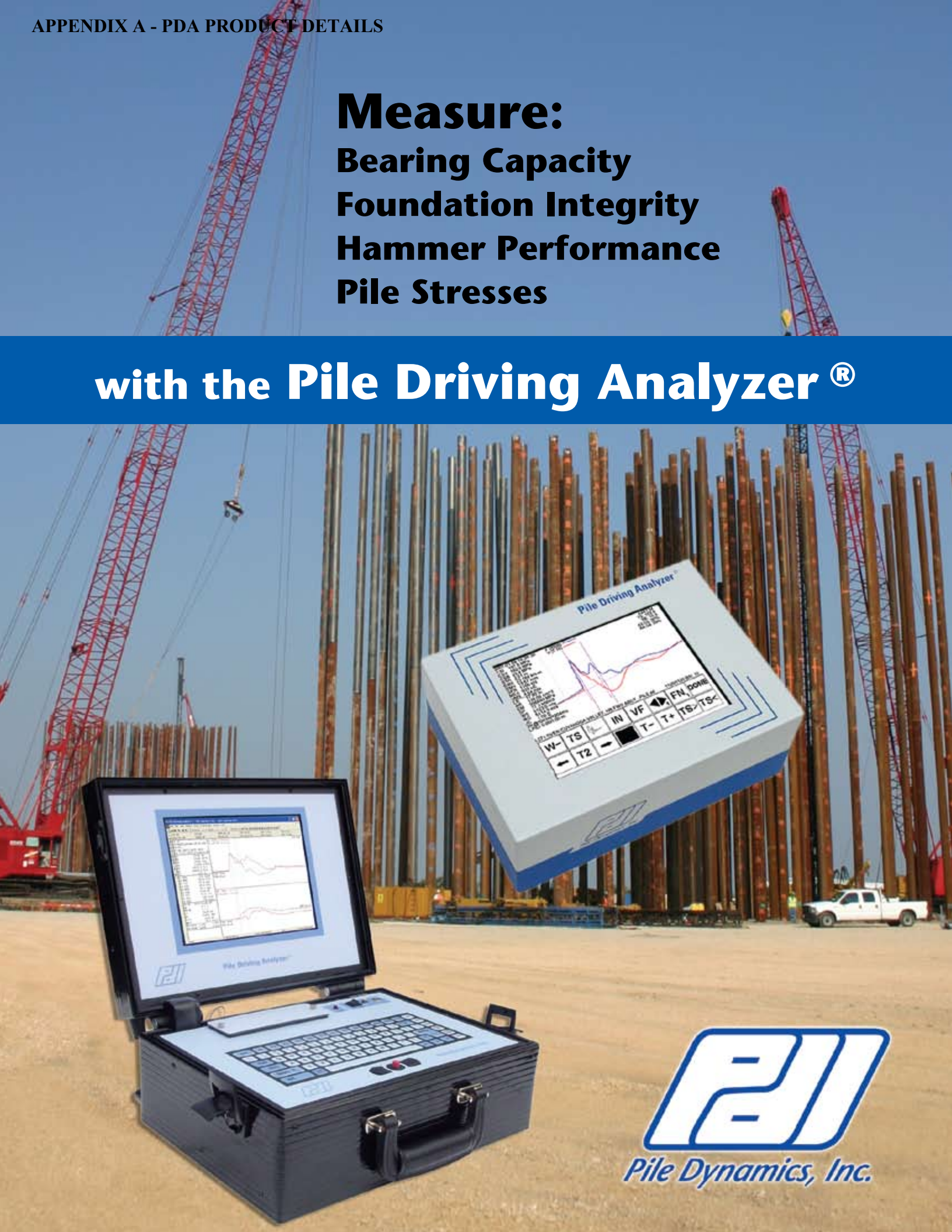
3 PROCEDURE

- PDA transducers shall be mounted at minimum distance of 1.5~2 times diameter of the test pile measured from pile top
- Drill 3nos. 6mm diameter holes on both opposing sides of the pile and fix transducers at the drilled holes using anchor bolts
- Check transducers for proper connection
- Place sufficiently thick plywood cushion (minimum 25mm) on top of the pile and place hammer at pile top
- Deliver first hammer impact to check hammer alignment. Adjust where necessary
- Proceed to deliver subsequent impacts (with higher drops if necessary) until sufficient data is acquired
- PDA unit captures, stores and displays all impacts in real-time
- Stored data shall be retrieved at later stage for further analysis and reporting

Measure:

Bearing Capacity
Foundation Integrity
Hammer Performance
Pile Stresses

with the Pile Driving Analyzer ®



Pile Driving Analyzer® (PDA)

For Dynamic Load Testing and Dynamic Pile Monitoring

The PDA verifies the bearing capacity of all types of drilled or driven deep foundations. Tests are quick and non-destructive.

Pile Driving Analyzers acquire data from acceleration and strain sensors attached to the foundation, and process these signals as the foundation element is impacted by a pile driving hammer or other suitable drop weight. This process is called High Strain Dynamic Test, and may take the form of **Dynamic Pile Monitoring** or of a **Dynamic Load Test.**

Dynamic Pile Monitoring is performed during initial driving of piles and provides information on **driving hammer performance, driving stresses, pile integrity** and **capacity at the time of testing**. When performed on test piles it can help establish a driving criterion, and during the production phase it contributes to a safe and economical pile installation.

Dynamic Load Tests are performed on drilled shafts, continuous flight auger, cast in situ or driven piles to determine their ultimate **bearing capacity**. The test consists of acquiring PDA data and analyzing it with the CAPWAP® software. Dynamic Load Test results correlate very well with foundation capacities obtained from conventional static load tests. The test also confirms the structural integrity of the foundation element.

The PDA also evaluates the energy of SPT Testing Equipment by force and velocity measurements.

The Pile Driving Analyzer® is available in two models:

PDA Model PAK
– a tradition improved for more than 15 years

The PDA model PAK was designed to meet the demands of rugged construction environments. It runs the PDA-W software during the high strain test, allowing the choice of nine out of more than 150 parameters for calculation and display in real time, with each hammer blow.

The latest PAK models run on Windows XP, permitting post processing and printing with PDA-W software and CAPWAP® analysis on the PAK itself. The PAK has a large color display screen and a sealed keyboard suitable for the field. It runs on AC or 12V DC (car battery), with a small internal backup battery for brief power interruptions.

The PAK collects and analyzes data from eight channels (four strain transducers and four accelerometers). It also monitors pile installation with a vibratory hammer.

Four or eight channels?

Most High Strain Dynamic Tests can be performed by acquiring data from 2 strain transducers and 2 accelerometers installed near the top of the foundation. Four channels of data acquisition are sufficient in this case.

Eight channels are strongly recommended for dynamic tests of augered cast-in-place piles and drilled shafts. Spiral-welded pipes often also benefit form eight channels. Eight channels are also essential for instrumentation when a set of acceleration and strain transducers is installed at a second location along the length of the foundation (for example by embedding sensors near the toe of a concrete pile). If the drop weight is to be instrumented to measure force by Newton's Law, then eight channels are also required.

PDA Model PAX – a full featured PDA with Internet data transmission

PAX, the most recently introduced model of PDA, features many improvements over earlier models, most notably broadband Internet data transmission. It is sufficiently small to be portable, is battery operated, and weighs only about 5 kilos. Its touch screen display doubles up as control panel and keyboard, and has extremely high visibility in all lighting conditions.

The PAX is available with either four or eight channels of data acquisition. It runs on Windows XP and may be used in either Local or Remote mode.

For those that opt to be present during the dynamic test, the PAX ***Local Mode*** has capabilities that mirror the model PAK. This mode of operation gives the field engineer access to more than 150 variables of interest in real time, displaying results and measured signals on the PAX screen as the high strain test is being performed.

When in ***Remote Mode***, the PAX offers a straightforward software interface for use on site by a technician trained to attach the sensors to the foundation and to the PAX and initiate data transmission. An engineer at a remote office computer running PDA-W receives the data collected by the PAX and has the ability to perform comprehensive monitoring and analysis in real time. Field to office data transmission is immediate, via broadband Internet.

The Pile Driving Analyzer model PAX is compatible with Pile Dynamics' Smart Sensors and Wireless Sensors.

Remote Testing

Pile Dynamics introduced the idea of collecting dynamic testing data from a job site and immediately transmitting it to a remote office computer back in the late 1990s, and was granted a patent* for the first remote data transmitting PDA (the PAL-R) in 2001. PDA users in Australia, United Kingdom, Sweden, Malaysia and other countries immediately embraced remote dynamic testing. These early adopters realized that sending only the PDA to the job site, and remaining in their office using the PDA-W software to monitor the test would give them a competitive advantage. They could offer their clients tremendous scheduling flexibility and enjoy no down time due to travel or weather delays.

*Remote Pile Driving Analyzer U.S. Patent No. US 6,301,551 B1

Software

The Pile Driving Analyzer is furnished with:

PDA SOFTWARE SUITE:

PDA-W, PDIPLOT and PDI-CURVES

• **PDA-W** controls the PAK data acquisition (this function is performed by the PAX software in the PAX) and processes PAK and PAX data files, either in real time or after the conclusion of the test. PDA-W data is interpreted for soil resistance at the time of the test, and, for driven piles, compression stresses induced at top and bottom, tension stresses along the shaft, energy transferred to the foundation and pile integrity. In total, PDA-W calculates over 150 high strain dynamic testing parameters in real time and displays the values of critical results compared with user specified target values. PDA-W also permits the creation of a driving log, and issues quality alerts during data acquisition.

• **PDIPLOT** summarizes large quantities of PDA calculated results and plots up to six quantities versus blow number, length or elevation. It also generates data tables, comments, and the blow count based on the driving log. PDIPLOT also calculates the efficiency of hammers with energy that varies from blow to blow (drop or hydraulic hammers). It provides the statistical summary output required by ASTM D4945.

• **PDI-CURVES** summarizes smaller groups of PDA calculated results, such as from re-strikes or dynamic load tests of drilled shafts. It combines plots versus time of Force-Velocity (required by ASTM D4945), Wave Up-Wave Down, Energy – Displacement and Force-Velocity-Wave Up from multiple PDA-W files in one single document. PDI-CURVES - displays up to 5 customized graphs – five blows of a drilled shaft dynamic test, or one representative blow from up to 5 driven piles - on one page.

CAPWAP® uses force and velocity records measured by the PDA sensors to, by signal matching, determine resistance distribution and dynamic soil response and simulate a static load test. Hundreds of comparisons demonstrate the high correlation of CAPWAP analysis with static load testing results. CAPWAP analysis of PDA data is standard practice for capacity evaluation by the Dynamic Load Testing method.

GRLWEAP is a wave equation analysis program that simulates pile driving, helping select the right hammer for pile driving or the adequate drop weight system for the Dynamic Load Test of a drilled shaft.

High Strain Dynamic Tests are standardized by ASTM D4945. All models of PDA, as well as Pile Dynamics strain transducers and accelerometers, conform to, or exceed, those standards.

High Strain Dynamic Tests performed with the Pile Driving Analyzer are recognized by:

- Eurocode 7
- American Society of Civil Engineers (ASCE)
- American Association of State Highway and Transportation Officials (AASHTO)
- Deep Foundations Institute (DFI)
- Federal Highway Administration (FHWA)
- International Building Code of the US
- US Army Corps of Engineers
- Pile Driving Contractors Association (PDCA)
- Numerous state Departments of Trasportation

Please contact Pile Dynamics for information on compliance with standards from other countries. Engineers around the world have been using the PDA for more than 35 years.

For current PAX and PAK technical specifications visit www.pile.com/specifications.

Both models operate in English, SI and Metric units and include technical manuals, one year warranty and continuing technical support.

Pile Dynamics, Inc.

Quality Assurance for Deep Foundations

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APPENDIX B – PREPARATION OF TEST PILE & SENSOR BOLTING DETAILS

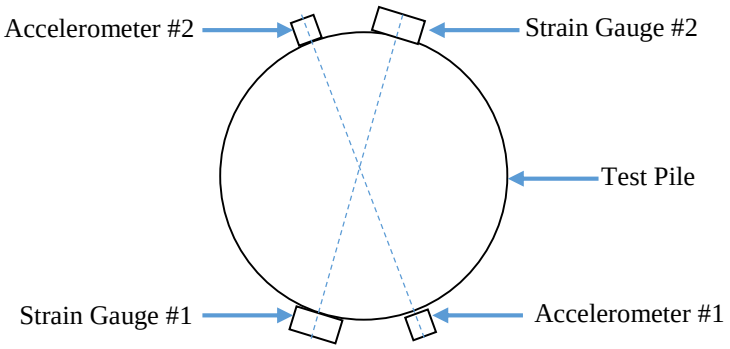

Figure 1 Plan of Pile showing Sensors Positions

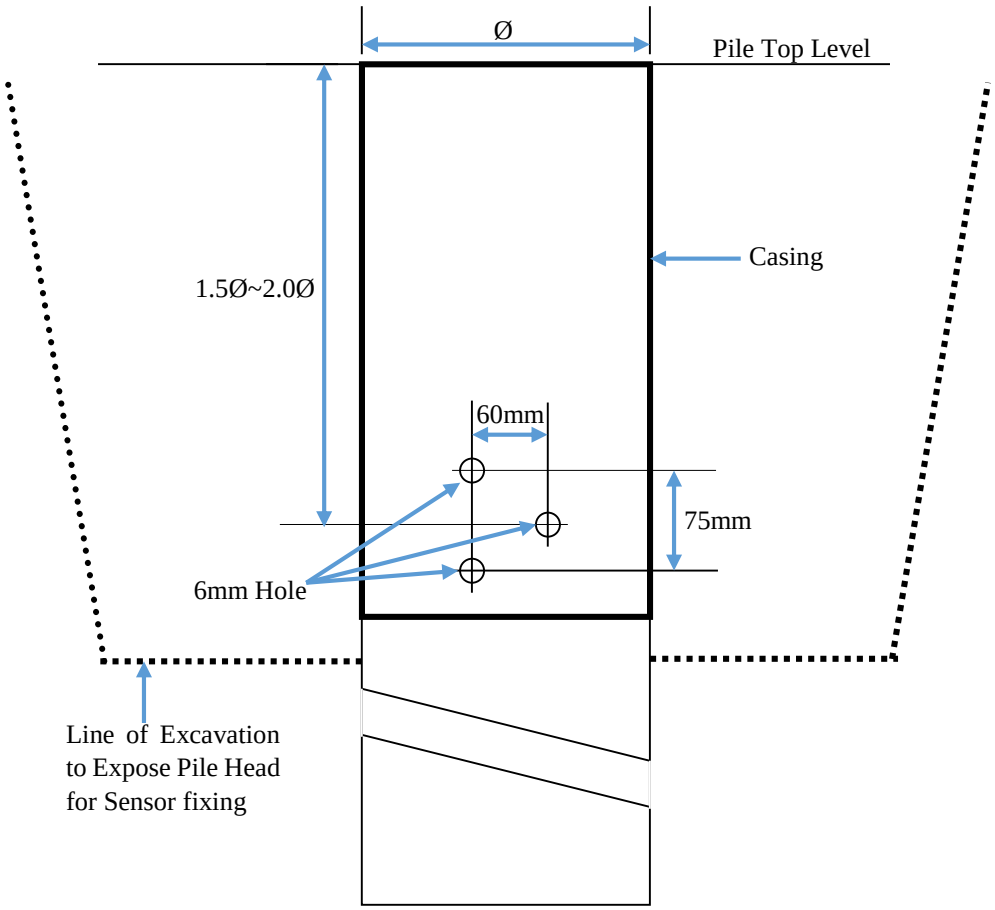

Figure 2 Elevation of Pile showing Sensors Positions

SINGAPORE LABORATORY
ACCREDITATION SCHEME

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ACCREDITATION COUNCIL

Number : **LA-2003-0279-B**

Date of Issue : **13 March 2016**

Date of Expiry : **12 March 2020**

Certificate of Accreditation

This certifies that

Soil Dynamics (S) Pte Ltd
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is accredited by the Singapore Accreditation Council to

ISO / IEC 17025 : 2005

for specific scope within the field of

Civil Engineering Testing

as detailed in the attached schedule.

Chairman