ANNEX "A"

TEST PROCEDURES FOR HIGH STRAIN DYNAMIC TESTING (PDA)

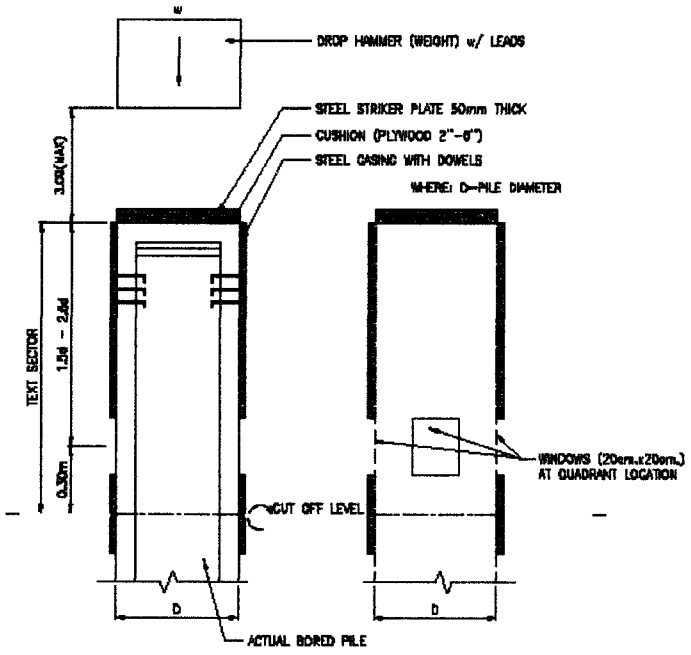
PRINCIPLES OF HIGH STRAIN DYNAMIC TESTING

The High Strain Dynamic Tests are performed using the Pile Driving Analyzer (PDA) PAK, PAL-K or PAX Model manufactured by Pile Dynamics Inc. (PDI), USA , which utilizes the *Case Method*[1] to obtain quick quantitative results at the site. Force and velocity records are continuously viewed from the PDA monitor for each blow to evaluate data quality, the maximum hammer transfer energy delivered to the pile, pile integrity, pile stresses, and other pertinent information.

During the test, the PDA machine processes the record almost instantaneously and calculates values with some simplifying assumptions using the Case Method. The results can be viewed on the screen to indicate values such as 1) maximum mobilized capacity for the specific blow (RMX); 2) the pile integrity factor (BTA); 3) maximum average pile compressive stress (CSX); 4) maximum delivered energy (EMX), etc. PDA testing is based on the principles of One-Dimensional Wave Mechanics (1DWM).

TEST PILE PREPARATION

The top length , defined as the "test area" (1.5 to 2.5 pile diameter extension plus 300 mm surface clearance for installation of gages) should be encased with steel casing to avoid damaging the pile head and shall be free from water, dirt or other debris. The concrete at the pile top impact area must be flat or level. *(See Figure 1)*



BORED PILE PREPARATION FOR PDA TESTING
FIGURE – 1

Hammer guide should be assembled to ensure the same and concentric impact of the hammer unto the pile.

Four windows (about 200mm^2), one each at four sides of the shaft at 90 degrees apart must be cut open in the steel casing to expose the concrete to allow installation of gages.

A steel cap cover shall be placed on top of the pile cushion for uniform impact distribution and to hold the pile cushion in place during testing. The size of the pile cushion should be roughly the same as the diameter of the pile while the steel cap cover should tightly fit the pile top.

TEST REQUIREMENTS

Prior to the dynamic test, the testing Engineer must be provided with soil boring data, shaft installation records, concrete properties (strength, etc) and details regarding the anticipated dynamic loading equipment.

The steel or concrete ram weight for testing the bored pile shall have a weight of at least 1.5% to 2% of the required ultimate pile bearing capacity as per plan.

At the time of testing, the bored pile shall have attained its 28 days compressive strength. Waiting period is essential to allow the previously disturbed soil to set-up and develop a natural bonding with the pile.

To fully activate the ultimate capacity of the pile, settlement should be:

Skin quake = 2.54 mm; shaking at the skin or pile shaft caused by dynamic wave or velocity

Toe quake = D/120; shaking at the pile toe caused by dynamic wave or velocity

EQUIPMENT

1. Pile Driving Analyzer (PDA) with four (4) Strain transducers and two (2) Piezoelectric accelerometers
2. CAPWAP software program
3. Surveying instrument to monitor the pile settlement after every blow
4. Hammer
5. Hammer guide
6. Cushion (50mm thick timber)
7. Steel plate cap cover
8. Crane
9. Computer

PILE TESTING PROCEDURE

Field instrumentation involves the attachment of four (4) strain transducers and two (2) piezoelectric accelerometers on diametrically opposite sides of the pile near the top. In general, these gages are 1.5 to 2.5 pile diameter (1.5D-2.5D) from the top. These are then attached to the PDA machine by connecting cables which will record the force/velocity traces of the wave according to the actual reactions of the pile.

When the gages have been placed in position and the Pile Driving Analyzer (PDA) had been calibrated, the input data such as Project Name (PJ), Pile Number (PN), pile length from the location of sensor to pile tip (LE), pile cross-sectional area in sq. cm at the transducers location (AR), pile modulus (EM), damping factor (JC), and embedded length of pile where resistance is measured (LP), will be encoded to the PDA. The Test Engineer shall instruct the client's crane operator regarding the drop height to release the steel ram weight to strike the test pile. The hammer shall be dropped from a gradual height increase as instructed by the Test Engineer. Usually 2 to 3 hammer blows will be applied. The data for each hammer blow will be viewed at the PDA monitor. The pile settlement for each blow shall be monitored at the surveying instrument during testing.

A representative blow will be selected from the total number of blows having the largest value of maximum delivered energy (EMX), a 100 % pile integrity factor (BTA) and a force-velocity proportionality equal to 1. The data shall be subjected for further analysis using the Case Pile Wave Analysis Program *(CAPWAP)*[2].

ACCEPTANCE AND REJECTION

The acceptance and rejection of a pile shall be based on the result of CAPWAP analysis. Pile which attained the required ultimate pile bearing capacity and with *impedance change*[3] of less than -10% will be accepted. Piles with impedance change of greater than -10% are considered to have serious defects and need further evaluation by the Geotechnical Consultant and the designer. Piles which failed to attain the required ultimate pile capacity and/or piles with impedance change of greater than -25% shall be automatically rejected.

REPORTS

- Description of test conducted including methodology, equipment and photographs.
- Complete test data of all trials/blows such as height of fall, mobilized capacity, wave speed, BTA and pile settlement, etc.
- Complete CAPWAP result.
- Evaluation and Recommendation.

[1] The *"Case Method"* refers to the methods developed at the Case Institute of Technology beginning in the 1960's. The objective is to calculate pile bearing capacity in real time for every hammer blow from pile top force and acceleration measurement. Today, the term "Case Method" refers to both measurement techniques and interpretations of soil effects, pile stresses, pile integrity and hammer performance by means of a Pile Driving Analyzer.

[2] *CAPWAP*, Case Pile Wave Analysis Program, is an iterative tool mainly used for capacity determination. CAPWAP combines measured force and velocity data with wave equation analysis to calculate the soil resistance force acting on the pile. After the data had been obtained in the field by PDA, this software program tries to match the measured force and/or velocity by numerically modeling the soil and pile system.

[3] A negative (-) *impedance change* suggests a decrease in pile cross-sectional area, a reduction on concrete modulus, or a combination of both. A positive (+) impedance change suggests an increase in cross-sectional area or bulging.

ANNEX "B"

CROSSHOLE SONIC LOGGING (CSL) TEST PROCEDURE FOR BORED PILES

PRINCIPLES OF CROSSHOLE LOGGING (CSL) TESTING

The Crosshole Sonic Logging (CSL) method is a downhole variation of the ultrasonic pulse velocity test using Crosshole Analyzer (CHA) manufactured by Pile Dynamics, Inc., USA or its equivalent. Ultrasonic transmitter and receiver probes are lowered down on the parallel tubes in the concrete (bored pile) to be tested, and the transit time of an ultrasonic pulse through the material between the tubes is measured by a data acquisition system. Water in the tubes provides acoustic coupling to the surrounding material. A continuous series of measurements is made as the probes are raised up from the tubes, providing a vertical profile of signal transit time.

The ultrasonic pulse velocity (UPV) is a function of concrete modulus, density, and Poisson's ratio, so the uniformity of the material can be assessed from the uniformity of the CSL profile. Irregularities such as soil inclusions, low modulus concrete, and voids will be readily detected and located by the increase in pulse transit time that they cause.

TEST PILE PREPARATION

Piles intended for Sonic Logging test are installed with 50mm inside diameter G.I. pipe access tubes at quadrant location. Minimum thickness of the tube is about 5mm. These tubes are preplaced as attached to the reinforcing cage prior to concreting. The tubes are installed continuously from bottom to the top of the pile and parallel to each other. The bottom ends of the tubes are provided with sealed cap or plugged to avoid intrusion and contamination of concrete during pouring and vibration. The tubes are fitted with robust couplings for extension to ensure that they remain watertight and to prevent slurry and grout ingress during pouring and curing of the concrete. The top of the tubes are plugged or secured to prevent entry of foreign objects, which could block the tubes prior to testing.

EQUIPMENT

1. Crosshole Analyzer (CHA)
2. Transmitter and receiver probes
3. Meter-wheel device
4. Computer
5. GI pipes (min. thickness=5mm)

PILE TESTING PROCEDURE

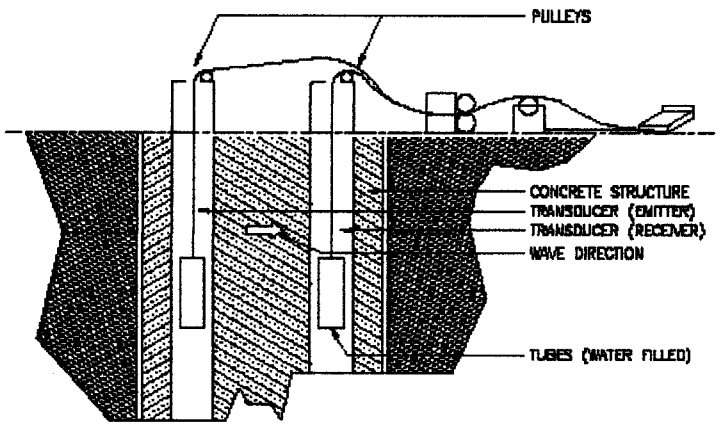
Prior to actual testing, all the access tubes were first checked to ensure that the tubes are not contaminated or blocked, and that they are reasonably straight, clean and free from any internal defects for the clear passage of the probes. This is done using a dummy probe to test access and at the same time record length of each tube.
The temperature of the water in the tubes is also checked. If the temperature exceeds the operating limits of the apparatus at 60°C (as when the concrete is only a few days old) then the test will have to be postponed until the pile has cooled down.

The access tubes are identified in the field as numbers 1, 2, 3, & 4. These are numbered sequentially in the clockwise direction.

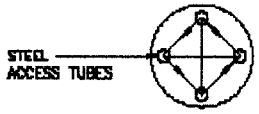
Prior to the test, the tubes are filled to the top with clear water. To ensure good acoustic coupling between the probes and the water in the tubes, the probes are cleaned and made fully saturated before each immersion.

The transmitter and receiver probes are then inserted inside the first two selected tubes for logging. If all the tubes are clear (not blocked), the tests normally start from the bottom progressing to the top. On the other hand, if any or all the bottoms of the tubes are blocked (i.e., bottoms are not in same elevation), then, tests are conducted starting from the top to bottom. A specific scan would then stop at the higher elevation of the two tubes being used, and this will now be reflected as the bottom of the specific record (but does not necessarily be the bottom of the pile). Measured pile length will therefore be shorter than actual. The cables of the probes are then made to run over the meter-wheel device for depth encoding. *(See figure 2)*

CROSSHOLE LOGGING (CSL) TEST
TYPICAL SITE SETUP AND TYPICAL SCAN CONFIGURATION



SCHEMATIC OF SYSTEM SETUP



SCHEMATIC OF
TYPICAL SCAN CONFIGURATION

Before commencing the logging, data input as to the project details, pile name, scans ID (i.e., 2-3, 1-2, etc.), are inputted as part of the record.

The equipment is then armed and recording is done by steadily pulling the probe cables simultaneously over the depth-encoding device. A speed of ascent appropriate to the method adopted for ultrasonic pulse generation is maintained until the probes are above the top of the pile. Enough time is allowed for any electronic data processing to finish before ending the recording process.

This process is repeated in all combinations of the access tubes. A total of six (6) scans or sonic maps are generated for the four access tubes of each pile.

ACCEPTANCE AND REJECTION

Pile is acceptable as to integrity if the results show no irregularities such as soil intrusions, low modulus concrete and voids. If such irregularities are noted, the integrity of piles needs to be evaluated by the geotechnical engineer/structural designer and the Bureau of Design (for projects approved by the Central Office) for any possible corrective measure. If the tubes are blocked and contaminated with concrete during pouring, the DPWH shall adopt the low strain dynamic testing (PIT).

REPORTS

- Description of test conducted including methodology, equipment and photographs.
- Complete test data (scans or sonic maps)
- Evaluation, analysis and recommendation.

Annex "C"

TEST METHODOLOGY OF LOW STRAIN DYNAMIC TESTING OR PILE INTEGRITY TESTING (PIT):

PRINCIPLES OF LOW STRAIN PILE DYNAMIC TESTING

Low Strain Method, also referred to as a Non-Destructive Method, is an integrity test for pile foundations, which is performed using a *Pile Integrity Tester (PIT)* manufactured by Pile Dynamics Inc. (PDI), USA.

Integrity testing is performed by affixing an accelerometer to the pile top and striking the pile with hand-held hammer with 1 to 2 lbs mass. The acoustic wave produced by the impact propagates down to the bottom end of the pile and the acceleration record created from each hammer impact is integrated to velocity and displayed on the high resolution screen of PIT. The Pulse Echo Method (PEM) records the pile top velocity as a function of time. The Transient Response Method (TRM) displays the mobility, i.e. the ratio of frequency spectra of pile top velocity and force. The data are later transferred to a computer for analysis and graphical output. A velocity record from a perfect pile shaft exhibits the impact, followed by a flat zero response, until a reflection from the toe is observed with the velocity profile similar to that of the impact event.

Variations in shape and material quality of the pile produce reflection as they return to the surface. Surface variations are recorded until all primary reflections have been observed. The deepest reflection is the pile toe, and the last to be observed. Given estimates of the wave speed (c) and the pile length (L), the toe reflection is expected at the time 2L/c after the impact.

TEST PILE PREPARATION

1. Remove the contaminated or loose materials and chip-off of the pile top to the required pile cut-off levels. Portion of the pile top surface will be evened out using a grinder so that the accelerometer could be attached and the hammer impact can be applied to a very clean, flat, dry and hard surface to have a uniform hammer impact. The test should be conducted at least 7 days after the concrete pouring of bored pile.
2. The accelerometer should be firmly attached using a thin layer of petroleum jelly, clay or pliable wax as bonding material in order to accurately measure the high-frequency motion during impact and reflection.

EQUIPMENT

1. Pile Integrity Tester (PIT)
2. Hand-held hammer
3. PITPLOT
4. Computer
5. Grinder

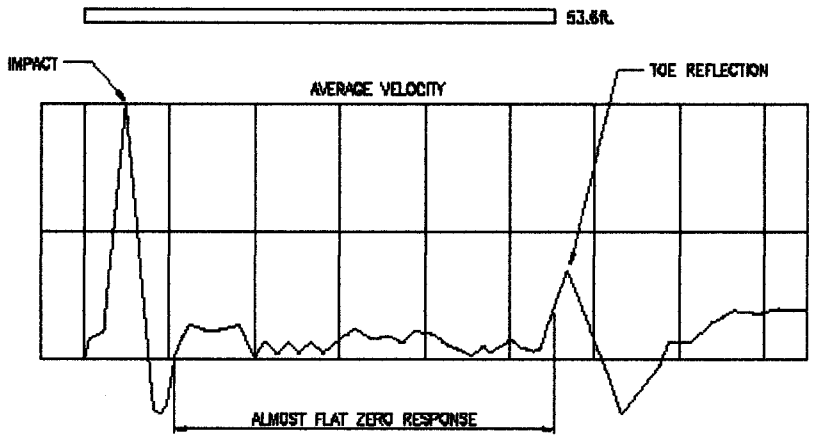
PILE TESTING PROCEDURE

1. The PIT which is a sonic test is done by applying five (5) blows each in every location and averaged by the PIT. This technique is useful in separating the effects of random mechanical and electronic noise from the relevant reflections. Instrumental hand-held hammer with 1 and 2 lbs mass shall be used for the tests.
2. The sonic test shall be repeated four (4) times at locations diametrically opposite sides (E, W, N, S), so that problems associated with poor accelerometer attachment or "unlucky" accelerometer placement or hammer hit spot will be avoided. The acceleration record is numerically integrated to produce the velocity signal.

3. The data are collected and further analyzed using PIT collector's processing and enhancement facilities *(PITPLOT)*[1].

ACCEPTANCE AND REJECTION

Concrete bored piles with only insignificant reflections other than the pile toe and with a clear pile toe reflection may be accepted *(See Figure 3).* Where no clear toe reflection is apparent, the experienced test engineer shall state to which depth the test appears to be conclusive. Where significant reflections from locations above the pile toe are observed, a quantification of the irregularity must be conducted by the Test Engineer. If such reflection indicates a significant pile impedance reduction, the pile must be rejected. If the record is complex the results may be deemed questionable. Construction records (concrete usage, grout pressure records, soil borings) may be valuable in results interpretation or additional numerical analysis modeling may be used to quantify the record. The results will be subjected for further review/approval by the Implementing Office.



MEASURED PILE TOP VELOCITY RECORD FOR SOUND PILE

Figure 3

REPORTS

- Description of test conducted including methodology, equipment and photographs.
- Complete test data of all trials
- Complete PITPLOT graphical results
- Evaluation and Recommendation.

[1] *PIT* is a state-of- the- art device for integrity testing.

[2] *PITPLOT* –Pile Integrity Testing Plotter Program

Annex "D"

The minimum requirements for Geotechnical Firms to perform the Pile Integrity Test (CSL or Low Strain) and PDA Test are as follows:

1. Company profile of the Geotechnical Consulting Firm
2. Certificate and proof of training attended by the Geotechnical Consultant and Technician
3. At least five (5) years experience in pile testing of Geotechnical Consultant and Technician duly employed by the Geotechnical Consulting Firm
4. Certification of ownership of testing equipments
6. Description of testing machines/equipments and test methodologies.