

## Module details

### Module 1 content (½ day):

- Basic principles of pile design
  - Design vs reality : the need to confirm capacity
  - Checking pile capacity on site – static testing
  - Checking pile capacity on site – dynamic formulae; set and temp compression
  - Pile driving, wave mechanics and stress waves
  - Does the contractor have the right equipment?
  - Assessing the set requirement for the first pile.
  - Measuring stress waves -gauges
  - Interpreting force and velocity measurements
  - Pile capacity – static and dynamic
  - Pile capacity – shaft and end bearing
  - The Case Method and damping factors
  - Checking the pile length
  - Hammer performance for different hammer types
  - Checking hammer performance with PDA
  - Dangerous driving situations in pile driving
  - Checking pile stresses with PDA
- On-site demonstration of PDA testing (½ day)
- What happens when a pile is overstressed?
  - Checking for pile damage with PDA
  - Comparing set and temporary with the PDA
  - Comparing PDA results and the Hiley formula
  - Improving the set requirement based on PDA testing
  - Analyzing dynamic test results in the office – the CAPWAP program
  - CAPWAP results – resistance distribution
  - CAPWAP results – static load-movement curves
  - Comparing CAPWAP and static load tests
  - Time effects – setup and relaxation
  - Driving and re-strike testing
  - Pile types for PDA testing

- Checklist for on-site supervision of PDA testing

## Module 2 content (1 day) Fundamentals of PDA testing

- General introduction to dynamic pile testing
- Measurement of stress waves
- Measurement of strain
- Strain transducer characteristics
- Measurement of acceleration
- Accelerometer characteristics
- Converting acceleration to pile-top velocity,  $v$
- Guide to transducer attachment : all pile types
- Pile cross-sectional area, [AR]
- Pile modulus, [EM] : steel, concrete and timber
- Converting strain to pile-top force,  $F$
- Pile specific weight, [SP] : steel, concrete and timber
- Pile wave speed, [WS] : the link between EM, SP and WS
- Pile impedance, [Z] : proportionality btw. force and velocity ( $F$  and  $v$ )
- Pile length, length below transducers [LE] and pile penetration [LP]
- Local wave speed (WS) and overall wave speed [WC]
- The wave-return time  $2L/C$  [ $2*LE/WC$ ]
- Basic introduction to Static resistance [RS] and Dynamic resistance [RD]
- &bullet;Basic introduction to Damping factor [JC] : dependence on soil type

## Field Testing

- Procedures and good practice for attachment of transducers to piles (all types)
- Minimum required numbers of transducers
- Checking transducer performance
- Specification for recalibration
- Entering transducer calibrations
- Strain offset, and checking strain offset [OF]

- Trigger selection
- Field sheet; data entry and site records
- Procedures for driving tests; end-of-driving tests and re-strike tests
- Driving test increment [LI]
- Physical measurement of set and temporary compression
- Entering project information [OP], [PJ], [PN], [PD]
- Digitization frequency [FR]
- Maximum blow rate [MB]
- Site safety
- Electrical safety : AC vs DC equipment
- General safety around construction equipment, hammers and piles
- Location to set-up for measurement
- Care for transducers, leads and connections
- Display mode [DP]. Different display options
- Screen graphic scales [FS, VS, ES, DS]
- Changing the time scale [TS, F8]
- Entering comments [PC]
- Numeric data output [Q1 thru Q9]. Brief description of available output. Recommendations for standard output.
- Trouble shooting for data problems
- Checking data quality [display command DPFV]
- Correcting for bending
- PDA graphs demonstrating :Bending
- Strain transducer slippage
- Clipped signals
- Transducers incorrectly aligned
- Incorrect calibrations
- Electrical noise
- Cable and connection problems
- Accelerometer malfunction
- Proportionality issues

This theory module is to be completed prior to the first of two single-day modules delivered on site. The

on site training component is to be delivered on sites provided by the client. One or more sites should be chosen to enable trainees to get experience with a range of pile types and hammer types. It is desirable but not essential that the on site training incorporate re-strike, end-of-driving and driving sequence tests.

#### Module 3 content (1/2 day)

- Safety reminder.
- Pile preparation, incl. drilling holes, use of template, setting anchors, bolt length and washers, attaching transducers.
- Equipment set-up, incl. positioning of vehicle, power-up, cabling, checking functioning and adjusting offsets, entering parameters.
- Data collection, recording, data review and adjustment, saving data and parameters, save frequency [SX and SQ]
- Checking data quality
- Adjusting for bending effects
- Checking for effect of cushioning
- Checking for effect of hammer stroke
- Taking set and temporary compression
- Replaying data
- Force/velocity proportionality [FVP] and adjusting modulus
- $2L/c$  time and adjusting wave speed input
- Printing graphic and numeric output summary in the field

#### On-site training (1 day)

#### Module 4 content (1 day)

- Quick review of fundamental equations for the link between EM, SP and WS proportionality btwn force and velocity (F and v) the wave-return time  $2L/C$  [ $2*LE/WC$ ]

- Sign conventions for force and velocity
- Wave mechanics animations & Newton's balls; balls with interconnecting springs; free and fixed ends; force/velocity
- Group exercise & human analog of wave mechanics
- Wave mechanics & mathematical approach
- Wave in an infinite pile with no resistance;  $f(x, t)$
- Wave in an infinite pile with no resistance & effect at  $x = \text{constant}$
- Limiting end conditions for finite piles
- Reflection from pile with free end (zero resistance)
- Characteristic easy driving signature
- Concerns for real piles with low resistance (easy driving)
- Reflection from pile with fixed end (infinite resistance/stiffness)
- Characteristic hard driving signature
- Concerns for real piles with high end bearing (hard driving)
- Reflections from intermediate end bearing resistance
- Reflections and transmissions from shaft resistance
- Determining the time of reflection
- The effect of the end bearing resistance displacement function
- Locating the pile toe tension response
- The physical meaning of upward and downward traveling waves
- Animations & upward and downward traveling waves
- The force/velocity proportionality for upward and downward waves
- Derivation of  $\dot{F}$  and  $\dot{V}$  from  $F$  and  $V$
- PDA  $\dot{F}$  and  $\dot{V}$  graph
- The equivalence of  $(\dot{F}, \dot{V})$  and  $(F, V)$
- The effect of downward and upward waves on  $(F, V)$
- Identifying compression and tension waves from  $\dot{F}$  or  $(F, V)$
- Identifying toe reflection

#### Module 5 content (1/2 day)

- Derivation of the Case Method for Total Capacity
- Dynamic resistance and velocity dependence

- Case Method damping factor [JC] - recommendations
- Case Method damping factor [JC] &ndash; typical values
- Damping and energy loss
- Assumed location of damping
- Pile toe velocity
- Derivation of the Case Method for Static Capacity
- Capacity as a function of displacement
- Mobilization of capacity : static and dynamic tests
- Capacity as a function of time
- PDA Resistance-time graphs
- The &ldquo;maximum resistance method&rdquo;, RMX
- Alternative strategies for estimating Case Damping factor
- Pile rebound
- Effect of unloading for long piles
- The &ldquo;Case method with unloading&rdquo;, RSU
- Estimating shaft resistance
- Limitations with estimating shaft resistance
- Estimating distribution of shaft adhesion
- Estimating end bearing
- Separating shaft resistance and end bearing
- Uplift capacity
- The sensitivity of Case Method Capacity to  $2L/c$  and JC
- Review and quantitative manual analysis of example pile testing records
- Comparisons of static and dynamic tests
- Static pile test comparison issues
- Kentledge vs hammer energy analogy
- Time dependent capacity changes
- Restrike testing
- Pile set-up
- Pile relaxation
- Combining driving and restrike test results
- Case histories of comparisons

## Module 6 content (1 day)

## Construction control – hammer performance

- Hiley formula
- Set and temporary compression (tc)
- Relationship between set, tc, DMX and DFN
- Potential, kinetic and transferred energy
- Relationship to Hiley formula energy assumptions
- Computation of energy transfer
- Transfer losses
- Hammer efficiency &ndash; standard GRLWEAP values
- Transfer efficiency &ndash; typical ranges
- Hammer characteristics
- Hammer malfunction
- PDA output quantities for energy and hammer performance
- Recommendations for driving system monitoring
- Effect of cushioning on transfer efficiency
- Effect of stroke on transfer efficiency
- Effect of soil resistance on transfer efficiency
- PDA energy-time and displacement time graphs
- The PDA quantities QUT and QUS
- Linking PDA testing and Hiley formula
- The Hiley formula and RX0
- The relationship between capacity and FMX
- The relationship between capacity and EMX/DMX
- Review of example data to highlight hammer performance issues

## Construction control – pile stresses

- Pile stress at the transducer location
- Bending

- Average and local stresses (pile top)
- Computing stresses below the transducer location
- Superposition of waves
- Critical conditions and locations for tension stresses
- Computing maximum tension stress in easy driving
- Computing maximum tension stress in hard driving
- Critical locations for compressive stress
- Computing maximum force at the pile toe
- Average and local stresses (pile toe)
- PDA output quantities for forces and stresses
- Allowable stresses (all materials)
- Strategies for controlling pile stresses – easy and hard driving
- Review and quantitative manual analysis of example pile testing records

#### Construction control – pile damage

- The Case model for pile damage
- Derivation of integrity factor,  $\beta$ ; [BTA]
- Location to damage [LTD]
- PDI broad recommendations
- Other issues to be considered with pile damage
- Progression or stabilization of damage
- Pile splice response
- Notional width of pile splice
- Damage and soil resistance
- Detection of damage during driving and restrike
- Review and quantitative manual analysis of example pile testing records

#### Module 7 content

This theory module is to be completed prior to the second of two single-day modules delivered on site. The on site training component will be delivered on sites provided by the client. One or more sites should be chosen to enable trainees to get experience with a range of pile types and hammer types. It is desirable but not essential that the on site training component incorporate restrike, end-of-driving

and driving sequence tests.

- Pile preparation and testing, particularly driving sequence
- Data collection, review and on-site analysis
- Force/velocity proportionality [FVP] and adjusting modulus
- $2L/c$  time and adjusting wavespeed input
- Evaluation of stresses, and integrity, and setting installation control procedures to ensure appropriate stress levels
- Evaluation of hammer performance, and change of transfer efficiency during installation sequence
- Estimation of pile capacity, including Case damping factor; adjustment of damping factor during sequence
- Comparison of maximum and final displacement values with physical measurements on site; adjustment as appropriate
- Comparison of PDA and Hiley capacities
- Developing installation set and temporary compression values for acceptance of untested piles
- Selecting appropriate output parameters
- Printing graphic and numeric output summary in the field

On-site training (1 day)

Module 8 content (1 day)

- Pile acceptance criteria &ndash; historical
- Basic introduction to Wave Equation Analysis
- Forecasting and hindcasting
- The driving system &ndash; internal and external combustion hammers
- Vibratory hammers
- Hammer components &ndash; ram, anvil, assembly
- Hammer losses and efficiencies
- The hammer database
- Pile and hammer cushions

- Cushion database
- The pile model
- Pile properties and impedance
- Modelling splices
- The soil model
- Static soil resistance models
- Smith dynamic soil resistance models
- Alternative damping models
- Resistance distribution
- Soil model extensions
- Residual stress analysis
- Analysis types
- Bearing Graph &ndash; proportional resistance
- Bearing Graph &ndash; constant shaft resistance or constant end bearing
- Inspection Chart
- Driveability Analysis
- Soil gain/loss factors; recommendations
- Output options
- Stresses
- Hammer stroke
- Driving time
- Variation of parameters with time
- Matching GRLWEAP to PDA testing

#### Module 9 content (2 days)

- Principles of Wave Equation analysis of dynamic measurements
- CAPWAP program flow
- CAPWAP algorithm for wave transmission and reflection
- Adjustment of data in PDAWIN
- Importing dynamic measurements into CAPWAP

- Pile specifics [PS]
- Wave, Force or Velocity matching
- Approach to wave matching
- Match Quality
- Blow Count match options
- When is a match OK?
- Subjectivity
- Pile Model adjustment [PM]
- Static resistance and resistance distribution
- Static resistance model parameters [QS, QT, TG]
- Dynamic resistance model parameters and options [JS, JT, SS, ST, OP]
- Static unloading model parameters [UN, CS, CT, LS, LT]
- Miscellaneous input parameters [PI, PL]
- Radiation damping model [SK, BT, MS, MT]
- Effect of parameter changes on match quality
- Pile impedance changes
- Pile compression and tension slacks
- Damping modification
- Quake modification
- Multiple toe analysis
- Residual stress analysis
- Multiple blow analysis
- Output Options
- Static analysis
- CAPWEAP
- PEBWAP
- Correlation with Case Method

#### Module 10 content (1/2 day)

- Testing of composite piles (non-uniform)

- Testing of composite piles (uniform)
- Testing of unusual pile sections, e.g rails and triangular sections
- Testing of drilled shafts
- Preparation of pile heads
- Testing of concrete-filled pipes
- Testing of concrete-filled pipes with thin casing
- Testing of concrete-filled pipes with thick casing
- Testing of CFA piles
- Testing of micropiles
- Testing of tapered piles and timber piles
- Testing of spiral-welded steel piles
- Considerations for open-ended tube piles
- Heavier ram or higher drop?
- Testing steel piles with high yield strength
- Diesel hammers and precompression
- Air/steam hammers and preadmission
- Estimating pile length : issues
- Recommendations for using followers
- Guidelines to hammer size and stroke requirements

#### Trial Exam (Part A)

- Part A1 is 12 general questions on data acquisition
- Part A2 is 8 questions with data analysis

#### Trial Exam (Part B)

- Part B1 is 10 general questions on data interpretation
- Part B2 is 8 questions with data analysis

## High Strain Dynamic Pile Testing Examination (1/2 day)

### Content:

- Part A is a 90 minute multiple-choice examination with 45 questions on data acquisition
- Part B is a 120 minute multiple-choice examination with 45 questions on data interpretation using Case Method analysis.

Both Parts can be taken as a combined examination.

### Outcomes :

- A candidate achieving a pass in Part A only will be given a Certificate of Testing proficiency at Basic, Advanced or Expert levels.
- A candidate achieving a pass in Part B only will be given a Certificate of Interpretation proficiency at Basic, Advanced or Expert levels.
- A candidate achieving a pass in both parts will be given a Certificate of Testing and Interpretation proficiency at Basic, Advanced or Expert levels.