1.1. Scope

- This specification describes the requirements for supplying, transporting, storing, handling and installation of piles.
- Type of pile covered in this specification are Precast Concrete Piles

1.2. Reference codes

When adopted in this specification or in other Contract Documents, the latest edition of the following codes, standards, specifications and references in effect on the date of contract award shall be used except as otherwise noted.

1.2.1. *Industry Codes and Standards*

- American Society for Testing and Materials (ASTM)

- ASTM A615 - Standard Specification for Deformed and Plain Billet Steel Bars for Concrete Reinforcement
- ASTM D1143 - Standard Method of Testing Piles under Static Axial Compressive Load
- ASTM D3689 - Standard Test Method for Individual Piles under Static Axial Tensile Load
- ASTM D3966 - Standard Test Method for Piles under Lateral Loads

- American Welding Society (AWS)

- AWS D1.1 - Structural Welding Code – Steel

- American Concrete Institute (ACI)

- ACI 543R – Design, Manufacture and Installation of Concrete Piles

2. GENERAL

2.1. Soil Conditions

Piles shall be designed referred to the soil proprieties identified in the appropriate boreholes locations. All recommendations included in the soil investigation report shall be taken into consideration.

2.2. Submittals

2.2.1. *Precast Concrete Pile*

Contractor shall submit the following information to Company for review and approval

- All design calculations and/or fabrication drawings for piles, including connections and splices.
- Proposed manufacturer(s)
- Concrete mix design and basis for mix

- Method of curing
- Sampling and testing procedures
- Certified test reports showing compliance with all related specification for all materials to be used for manufacturing of piles, including strands, wire, cement, aggregates, admixtures, and curing

2.2.2. *Pile Load Test*

Contractor shall submit shop drawings of the loading apparatus and arrangement of the test and all design calculations. In addition, include current calibrations of load-cell and pressure gauge.

2.2.3. *Pile-Driving Record*

Submit on a daily basis, one copy of completed pile-driving record form of each pile, including but not limited to the following information:

- Project name, number, and location
- Name of Contractor and Subcontractor
- Structure identification
- Date of pile installation
- Pile location and identification number
- Pile type, size, and length
- Pile tip and ground elevation
- Hammer type, model and rated energy
- Other installation equipment including details on use of pile cushion, follower, mandrels, pre-drilling, and water jet if applicable
- Time for start and finish of driving pile
- Penetration under own weight and penetration under own weight plus weight of hammer
- Driving data in number of blows per 250 mm from initial to final driving and number of blows for last 150 mm penetration.
- Splice types and locations
- Records of re-striking
- Interruptions (reason, time, duration, tip elevation)
- Deviations from specification
- Notation of any unusual occurrences during installation or of any observed pile damage
- Signature and title of inspector recording pile-driving data

3. PRODUCTS

3.1. General

All Contractor-supply materials and proprietary items, including splice devices, tip protectors, driving shoes, tension or uplift connectors, etc., shall be subject to approval and shall be installed in accordance with manufacturer's instructions.

All concrete shall conform to requirements of General notes for steel & concrete structures.

3.2. Welding

Welding shall be performed in accordance with AWS D1.1 and AWS D1.4, welding filler metal shall be AWS D1.1-98, Section 3.3 (including Table 3.1) with electrode strength of 400 MPa minimum yield strength and 480 MPa minimum tensile strength. (For example, use E70XX for SMAW, F7XX-EXXX for SAW, ER70S-X for GMAW, and E7XT-X for FCAW.) However, E60XX electrodes may be used for tack welding.

3.3. Splicing

Splices shall provide true alignment of total pile. Splices shall be capable of transmitting all driving forces as well as all intended service loads.

3.4. Pre-stressed / Precast Concrete Piles

3.4.1. *Design and Manufacture*

Design and manufacture of concrete piles shall conform to *ACI 543R " Design, Manufacture, and Installation of Concrete Piles "*

3.4.2. *Pile Materials*

Pile materials shall be as follows:

- Concrete: minimum 35 N/mm^2 28-day strength unless specified otherwise in the Contract Documents
- Reinforcing bars: deformed, ASTM A615, Grade 60

3.4.3. *Pile Length Marking*

Pile length shall be marked on pile surface at 250 mm interval.

4. EXECUTION

4.1. Equipment

4.1.1. *Hammers*

Drive all piles with Impact Hammers capable of installing all piles to the specified capacity, resistance, and minimum depth. Drop hammers shall not be used unless approved in writing. Piles driven with faulty equipment shall be subject to rejection. Cost of removal or installation of additional piles shall be borne by the Contractor. Hammers shall not be operated at less than the speed and stroke length specified by the manufacturer.

4.1.2. *Leader*

Leads shall be held firmly in position by stiff braces. Axis of the leads, hammer and pile shall coincide.

4.1.3. *Cushioning*

Provide hammer cushions or cap-blocks of aluminum and micarta (or equal) discs stacked alternately in a steel housing or a suitable polymer designed for this specific purpose as indicated by the hammer manufacturer and with a steel plate at the top and bottom of cap-block. Alternatively, a one-piece hardwood cap-block, with grain parallel to the pile axis and enclosed in a close fitting steel housing, may be used. Satisfactory driving criteria shall be established with such a cap-block, and a new cap-block shall not be used during the final driving of any pile. Capblocks made from other materials are subject to approval. Wood chips, small wood blocks, wood shavings, or other materials with high-elastic properties shall not be used for cap-blocks. For pre-stressed piles, provide pile cushion appropriate for pile and hammer.

4.2. Installation

4.2.1. *General*

Drive piles to the indicated lines, grades and capacities required by the Contract Documents. Use driving cap or helmet to prevent damage to pile heads during driving. Do not use loose inserts in cap. Hold pile securely in proper position and alignment while driving. Deliver hammer impacts concentrically and in direct alignment with pile. Avoid forcing pile laterally or bending pile. Drive piles no closer than 6 m from concrete that has been in place less than 3 days. Drive piles continuously, without interruption, to the final tip elevation. A discontinuous driving operation shall be referred for resolution. Sudden resistance to pile driving by underground obstructions shall be made known and resolved. Install uplift connectors as determined by the Contract Documents. If a pile is damaged at the top during driving, the damaged portion shall be cut off. A damaged pile shall be made known and resolved. If necessary, a new length shall be spliced to the undamaged pile before resumption of driving. Piles in large groups shall be driven from the inside toward the outside. Care shall be exercised not to drive the pile beyond the depth of penetration required. Piles shall not be driven until the earthwork within the area has been completed to specified grade, unless otherwise required by the Contract Documents. If measured driving stresses in piles are deemed excessive, Contractor shall reduce the driving energy transmitted to the pile by reducing the energy output of the hammer or by using additional cushions. Contractor shall re-strike any heaved piles to meet the design requirement.

4.2.2. *Tolerances*

Pile heads, at cut-off elevation, shall be within 75 mm in any horizontal direction of the position defined in the Contract Documents. Pilings shall be cut off square, true, and level. Cut-off tolerance shall be within 25 mm of the required elevations defined in the Contract Documents. Vertical piles shall be plumb within 2% of the pile length. The maximum deviation from the required axial alignment of battered piles shall be within 4% of the pile length.

4.2.3. *Pre-drilling*

Pre-drilling pilot holes only when required by the Contract Documents. Pilot holes are subject to modification on the basis of the results of initial driving operations and analysis of driving data. Drill pilot hole no larger than the least dimension of pile minus 50 mm. Terminate pre-drilling at 1 m above pile tip elevation. Promptly remove and dispose of spoil produced by pre-drilling. Disposal shall be off the work area.

4.2.4. *Driving Criteria and Capacity Evaluation*

Contractor shall drive piles to the depths shown in the Contract Documents. Contractor shall continue driving beyond the minimum depth until meet the approved pile driving criteria. For the driving control of working piles, the definition of refusal for driven piles shall be obtained from the relationship of Geotechnical investigation report, PDA test result, Static Load Test result, monitored blow counts/penetration depth during PDA test and calculation result of Hiley's formula. When refusal is not defined, refusal shall be defined as last 10 blows based on the pre-decided driving energy. Driving criteria are subject to modification on the basis of analysis of initial and ongoing driving results. Lesser penetration to the specified minimum tip elevation will be permitted only when additional pile driving will damage the pile. If the pile-driving criteria are not met, or if penetration to minimum tip elevation is not reached, Contractor shall submit recommendations for remedial action for approval.

4.2.5. *Unsatisfactory Pile*

Contractor shall take action to correct rejected piles that do not meet all the requirements of this specification, including those piles that are damaged, broken, misplaced, driven improperly, or out of alignment. This may include extracting the rejected piles and driving new piles or driving additional piles.

4.2.6. *Precast Concrete*

Piles where anchor/dowel holes have been provided for uplift connection, shall be protected to prevent dirt or other substances from contaminating the hole before grouting.

4.3. Wave Equation Analysis

Prior to driving any pile, Contractor shall submit a pile Wave Equation Analysis for each size of pile, pile hammer and distinct subsurface profile condition. These analysis shall take in account the proposed hammer assembly, pile cap block and cushion characteristics, pile properties and estimated lengths and the soil properties anticipated to be encountered through the installed pile length based on static capacity analysis with consideration of driving gain/loss factors.

Wave Equation Analysis shall demonstrate that the pile will not be damaged during driving, shall indicate the driving stresses will be maintained within the limits below and indicate the blow count necessary to achieve the required ultimate static pile capacities.

Upon completion of dynamic and static testing program outlined in this specification section, a refined Wave Equation Analysis shall be performed taking into consideration the evaluated capacities, gain/loss driving criteria shall be developed based on the results of the refined Wave Equation Evaluation.

Pile and driving equipment data form, including hammer information, as part of the submittal of the result of Wave Equation Analysis.

4.4. Dynamic Pile Analysis

Dynamic testing shall be executed to provide supplementary information for evaluating pile hammer performance, driving stresses and bearing capacity of piles. Dynamic Testing shall be conducted during the entire time when piles are initially driven or re-driven and during pile re-striking testing. Equipment to obtain dynamic measurements, record, reduce and display its data shall be furnished and meet the requirement of ASTM D 4945.

With every fifth blow of the pile, the information listed below shall be electronically recorded and analyzed by the Pile Driving Analyzer.

- Blow number
- Blow rate per minute and/or stroke
- Input and reflected values of force and velocity
- Value of upward and downward traveling force wave with time
- Maximum and final transferred energy to pile, hammer system efficiency
- Maximum compressive stress, velocity, acceleration and displacement
- Maximum tensile stress in pile
- Pile structural integrity, damage detection, extent and location
- Bearing capacity of pile by case method

If the pile, hammer and soil performance evaluation recommends changes to the hammer stroke, pile cushion or any other aspect for the pile driving operation, these changes shall be incorporated into production pile driving in an effort to control excessive stresses and pile damage.

Selected initial driving records shall be subjected to rigorous computer analysis by the Case Pile Wave Analysis Program (CAPWAP) for determination of resistance distribution, soil resistance and properties, and estimation of anticipated gain/loss factors.

Upon completion of test pile driving, the pile shall be allowed to set-up for at least 72 hours. After evaluation of pile, hammer and soil performance, the second step of the dynamic pile analysis may proceed. This portion of the evaluation requires re-striking the test piles a minimum of 20 – 50 times using same hammer which was used for the test pile driving and which shall be used for production pile driving. Hammer should be warmed prior to re-striking the test pile by striking the ground or other object a minimum 30 blows.

In addition to those items listed above, selected re-strike driving records shall be subjected to computer analysis by the CAPWAP for properties, plot of applied load vs. average pile displacement based on the calculated soil properties.

As a minimum, the test pile indicated with the least resistance shall be subjected to CAPWAP analysis.

The report for Dynamic Pile Analysis shall contain the following information :

- Bearing capacity of pile from CAPWAP. Information resulting from analysis of a selected re-strike blow.
- Maximum and final transferred energy, hammer system efficiency during pile installation
- Maximum compressive stress, velocity, acceleration and displacement
- Maximum tensile stress in pile
- Pile structural integrity, damage detection, extent and location
- Blow per minute and blow number
- Input and reflection value of force and velocity, upward and downward traveling force wave with time
- Pile skin friction and toe resistance distribution
- Maximum energy transferred to pile

4.5. Static Load Test

4.5.1. *Static Compressive Load Test (if required)*

Compressive Static Load Test shall be performed for the number of piles as decided by design engineer in accordance with ASTM D 1143 (maintained test). Allow minimum 72 hours following final test pile driving for pile set-up prior to load testing. Test load and settlement limit shall be decided by design engineer.

4.5.2. *Tensile Load Test (if required)*

Tensile Load Test shall be performed in accordance with ASTM D 3689.

4.5.3. *Lateral Load Test (if required)*

Lateral Load Test shall be performed in accordance with ASTM D 3966.