SECTION 02380 – FOUNDATION PILES

PART 1 - GENERAL

1.01 DESCRIPTION OF WORK

A. The Work of this Section includes, but is not limited to, furnishing all labor, materials, equipment, and incidentals necessary to complete the following work:

1. Furnishing and installing the following:

    a. Parking Garage: 160 ton allowable design compression capacity, 16-in. square precast, prestressed concrete foundation piles at the locations shown on the Drawings, driven to end bearing with a minimum 360 ton ultimate capacity.
    b. Office Building: 125 ton allowable design compression capacity, 14-in. square precast, prestressed concrete foundation piles at the locations shown on the Drawings, driven to end bearing with a minimum 280 ton ultimate capacity.

2. Furnishing and installing steel bottom plates as outlined in this Section.
3. Conducting computer wave equation analyses by WEAP (Wave Equation Analyses for Piles) prior to mobilization and import of pile materials to the site in order (1) to determine the end bearing driving criteria for the pile to achieve the design compression capacity stated above and (2) to demonstrate that the stress levels in the piles do not exceed the allowable tensile and compressive strengths of the piles during driving to ultimate capacity with the proposed hammer-pile-soil system. WEAP analyses shall be conducted for all hammer-pile systems proposed to complete the Work.
4. Installing indicator piles at designated production pile locations and performing Dynamic Pile (PDA) testing on all of the indicator piles at locations shown on the Drawings. PDA testing shall be conducted prior to the start of production pile driving to confirm pile design capacities, evaluate the driving energy transferred to the pile during installation, determine stresses induced in the piles during driving, determine range of installed pile lengths, and evaluate performance of the pile driving equipment. Indicator piles are to be driven at a minimum of nine designated production pile locations for the Parking Garage and a minimum of four designated production pile locations for the Office Building. If more than one hammer type is used by the CONTRACTOR, a minimum of seven additional indicator piles will be installed and tested by the CONTRACTOR as determined by the ENGINEER.
5. Restrike up to five indicator piles (with the PDA measurements) between 24 and 48 hours after completion of initial driving.
6. Perform CAPWAP analyses on a minimum of four of the indicator piles at locations determined by the GEOTECHNICAL ENGINEER.
7. Installing production piles based on the WEAP analyses and the results of the dynamic testing.
8. Splicing piles as required.
9. Provide survey control, layout of design pile locations, pile heave measurements, pile cut-off elevations, preparation of as-built sketches and related survey control work.
10. Cutting off piles at design cut-off elevations and disposing pile cut-offs at approved off-site locations. Preparing the exposed end of the pile to receive the structural connection to the floor slab and/or pile cap.

1.02 RELATED WORK SPECIFIED ELSEWHERE

A. Section 02010: Existing Subsurface Conditions

B. Section 02110: Handling Contaminated Soils

C. Section 02220: Site Demolition

D. Section 02240: Dewatering

E. Section 02250: Lateral Support of Excavation

F. Section 02300: Earthwork

1.03 DEFINITIONS AND REFERENCE STANDARDS

A. ARCHITECT (Parking Garage): Scott Simons Architects, Portland, Maine

B. ARCHITECT (Office Building): Harriman Associates, Inc., Auburn, Maine

C. STRUCTURAL ENGINEER (Parking Garage): Becker Structural Engineers, Inc., Portland, Maine

D. STRUCTURAL ENGINEER (Office Building): Harriman Associates, Inc., Auburn, Maine

E. GEOTECHNICAL ENGINEER: Haley & Aldrich, Inc., Portland, Maine

F. ENGINEER: Authorized representatives of the OWNER. For the work covered under this Section, this term will include Haley & Aldrich, Inc., Becker Structural Engineers, Inc., and/or Harriman Associates, Inc.

G. CONTRACTOR: Person or organization identified in the Agreement as being responsible for the Work under this Section. The term CONTRACTOR shall also refer to an authorized representative(s) of the CONTRACTOR.

H. ASTM: Specifications of the American Society for Testing and Materials, latest edition.

I. AWS: AWS D1.1 Structural Welding Code – Steel, latest edition.

J. AISC: Specification of the American Institute of Steel Construction, latest edition.

K. AASHTO: Specification of the American Association of State Highway and Transportation Officials, latest edition.

L. ACI: Specification of the American Concrete Institute, latest edition.

M. PCI: Specification of the Prestressed Concrete Institute, latest edition.

N. OSHA: Occupational Health and Safety Administration.

O. IBC Code: International Building Code (2003 edition).

1.04 PROJECT CONDITIONS

A. Site, Subsurface Soil, and Groundwater Conditions:

1. A geotechnical data report summarizing subsurface conditions and a memorandum summarizing the results of a test pit exploration program have been prepared for the project by Haley & Aldrich, Inc. Refer to Section 02010 for this information.

B. In-Situ Fill/Obstructions

1. The CONTRACTOR is advised that the in-situ fill soils may contain former and existing utilities, concrete and other foundations and floor slabs from previous structures, rail lines and other materials which may interfere with new foundation locations and require removal. These items will not be considered obstructions and shall be removed as needed at no additional cost to the OWNER.
2. Pre-drilling of foundation piles may be required at pile locations prior to pile installation as described herein. The CONTRACTOR shall pre-drill where necessary to clear underground structures and other debris prior to pile installation. Pre-excavations shall be backfilled and compacted in a controlled manner prior to pile installation in accordance with Section 02300 using on-site fill materials with objects larger than 4 in. removed.

C. Review of Existing Information:

1. Prior to submitting a bid, the CONTRACTOR shall review and understand the information referenced in Sections 02010 and 02110 and other applicable resources. The referenced reports are made available to the CONTRACTOR for information only. The subsurface information and environmental conditions presented in these documents are for information only and shall not be interpreted as a warranty of subsurface or environmental conditions whether interpreted from written text, boring logs, chemical test results, or other data.
2. The CONTRACTOR shall draw their own conclusions regarding site conditions based upon site visit(s) and from available sources, for which the OWNER and its consultants assume no responsibility. The CONTRACTOR shall assume that subsurface conditions between subsurface explorations could differ from conditions shown in the records of the explorations.

D. Protection of Adjacent Property and Utilities:

1. The CONTRACTOR shall protect adjacent structures (above ground and buried) from damage associated with pile driving and other related operations. Damage due to pile driving or other construction activities shall be repaired immediately by the CONTRACTOR at their own expense.

1.05 QUALITY ASSURANCE

A. Comply with all rules, regulations, laws and ordinances of the State of Maine, City of Portland, OSHA and of all other authorities having jurisdiction. All labor, materials, equipment, permits and services necessary to make the work comply with such requirements shall be provided by the CONTRACTOR.

B. Field Monitoring and Testing:

1. In accordance with the requirements of the IBC Code, the GEOTECHNICAL ENGINEER will provide full-time monitoring of the CONTRACTOR'S pile driving operations. No piles shall be advanced except in the presence of the GEOTECHNICAL ENGINEER.
2. The GEOTECHNICAL ENGINEER will prepare and maintain pile driving records which include the following information:

a. Project name and number.
b. Name of CONTRACTOR.
c. Pile location and number.
d. Design pile capacity.
e. Type and size of hammer used.
f. Material type, dimensions, and thickness of any pile driving cushion between the hammer and pile.
g. Rate of operation of pile driving equipment.
h. Pile dimensions.
i. Elevation of tip.
j. Elevation of butt before and after cut-off.
k. Ground elevation.
l. Number of blows for each foot of penetration and final penetration resistance.
m. Pile location deviation.
n. Pile uplift and redrive information.
o. Unusual occurrences during pile driving.

C. The CONTRACTOR shall fully cooperate with the GEOTECHNICAL ENGINEER and the OWNER'S other representatives to facilitate all work of this Section.

D. The CONTRACTOR or the pile supplier shall provide daily quality control of concrete and other materials for pile manufacture at the plant. From time to time the ENGINEER may visit the plant to observe pile manufacturing.

E. Certification of quality and source of pile materials to be used in the work shall be furnished, in a form acceptable to the GEOTECHNICAL ENGINEER, at the time of delivery of materials to the site. Pile materials shall also be subject to on-site inspection by the GEOTECHNICAL and/or STRUCTURAL ENGINEER for conformance with specifications.

F. Approvals given by the GEOTECHNICAL ENGINEER or OWNER shall not relieve the CONTRACTOR of their responsibility for performing the work in accordance with the Contract Documents, nor shall they be construed to relieve the CONTRACTOR from their full responsibility for the means and methods of construction and for safety on the construction site.

G. The CONTRACTOR shall employ a Professional Engineer licensed in the State of Maine who specializes in geotechnical engineering to perform WEAP Analyses for all hammer-pile systems and types of piles, to conduct PDA testing, and to perform related CAPWAP analyses. The licensed Professional Engineer shall have not less than 5 years experience within the last 10 years in making consulting engineering recommendations, design, or supervising installation of pile foundations, and shall have completed WEAP analyses, PDA testing and CAPWAP analyses on not less than five unrelated, independent projects, in which piles were successfully installed using the pile driving criteria developed from the wave equation analyses and the load test results.

H. Qualifications of Contractor:

1. Shall have at least 3 years experience within the last 10 years in pile driving of similar type and complexity as the indicated pile foundations.
2. Shall have completed not less than 3 successful pile foundations of similar type and complexity as the indicated pile foundations within the last year.

I. All welding shall be performed by operators who have been previously qualified by tests as prescribed in the "AWS Standard Code for Welding in Building Construction". Evidence that

welders meet qualification requirements shall be submitted to the GEOTECHNICAL ENGINEER before welding has begun. Monitoring of welding and welds may be performed by an independent testing agency employed by the OWNER. The CONTRACTOR shall fully cooperate with the agency to facilitate inspection, notifying it at least one working day in advance when welding operations are to be performed. Welds that do not conform to applicable specifications shall be repaired as directed by the OWNER or their authorized representative.

1.06 SUBMITTALS

A. General:

1. The CONTRACTOR shall submit the information specified herein to the GEOTECHNICAL ENGINEER for review. All submittals and data shall be legible, provided in English, and stamped by a Professional Engineer licensed in the State of Maine and retained by the CONTRACTOR.
2. The CONTRACTOR shall adhere to the approved submittal schedule, making every effort for timely submissions and allowing adequate time for the GEOTECHNICAL ENGINEER to review, evaluate and respond to the CONTRACTOR. The CONTRACTOR is responsible for scheduling specified submittals and re-submittals so as to prevent delays in the work.
3. Unless otherwise specified, submittals shall be made not less than three weeks before the start of the work. No work shall be started until the necessary review and approvals have been given.

B. Shop Drawings:

1. Shop Drawings showing pile size, pile reinforcing, pile tip and splice details, pick up points and other items pertinent and as applicable to particular pile design and handling, including steel bottom plates.
2. Shop Drawings and design calculations for all items pertinent to pile manufacturing and handling/installation.
3. A tabular summary of anticipated pile lengths at each column location.
4. Shop Drawing showing pile layout and pile numbering.

C. Pile Driving and Dynamic Load Test Equipment:

1. Manufacturer's literature, including technical and performance literature for pile driving hammer(s), cushions, hoses, and other equipment for piles.
2. Details of equipment and procedures for pre-excavation or pre-drilling, as required.
3. Qualifications and experience of CONTRACTOR’S Professional Engineer performing the PDA testing and CAPWAP analyses.
4. Description of dynamic testing equipment and procedures.
5. Complete reports of PDA measurements/analyses and CAPWAP analyses performed during the indication pile program at least three working days prior to the commencement of the scheduled production pile driving.

D. Pile Design/Manufacture:

1. Name and address of pile manufacturer/supplier.
2. Effective prestress in piles.
3. With each delivery of piles, results of concrete strength tests conducted by a certified laboratory on samples cured in the same environment as the piles. No piles will be accepted unless accompanied by concrete strength data upon delivery.
4. Name and address of pile splice manufacturer/supplier.

E. Wave Equation (WEAP) Analyses:

1. Qualifications and experience of CONTRACTOR'S Professional Engineer performing the WEAP analyses.
2. The CONTRACTOR shall propose final driving criteria (blow count) as the minimum number of hammer blows for each inch of the final 6 in. of pile penetration in the bearing stratum for all hammer-pile systems. The proposed criteria shall be submitted to the GEOTECHNICAL ENGINEER for review. Piles shall not be installed prior to review of the criteria by the GEOTECHNICAL ENGINEER.
3. Results of WEAP analyses performed and stamped by a Professional Engineer licensed in the State of Maine, which demonstrate that all hammer-pile systems are capable of obtaining the required pile load capacity in accordance with the IBC Code without damage to the pile due to driving stresses. The WEAP analyses shall model bearing conditions in soil and bedrock, and anticipated pile lengths across the site. The submittal shall also include any additional applicable assumptions used in the analyses.

    a. Analyses over a range of final pile penetration resistance, from to 2 to 14 blows per inch.
    b. The minimum allowable toe quake used in the analyses shall be 0.04 in.
    c. The minimum allowable toe damping used in the analyses shall be 0.15 sec/ft.
    d. The maximum allowable compressive stress in the pile during driving shall not exceed the maximum allowable compressive strength of the concrete in accordance with the IBC Code (1808.2.3.3). Provide documentation showing the calculated maximum allowable compressive strength of the piles.
    e. The maximum allowable tensile stress in the pile shall not be exceeded during driving. Provide documentation showing the calculated maximum allowable tensile strength of the piles in accordance with Section 1809 of the IBC Code.
    f. The minimum resistance from the pile tip shall be 90 percent.
    g. The hammer efficiency shall be selected based on the wave equation program default for the selected hammer.

F. Pile Dynamic (PDA) Testing:

1. Report summarizing the results of the PDA testing and CAPWAP analyses conducted by the CONTRACTOR'S Professional Engineer.

G. As Driven Pile Location Data:

1. Submit sketch and tabular documentation of actual pile location in relation to the design location within one working day after each individual pile is completed.
2. Within seven (7) days after the completion of all pile driving and re-driving, submit to the Owner a final as-driven pile location drawing (1 in. = 20 ft), certified by a Land Surveyor licensed in the State of Maine.
3. All drawings and sketches shall include the following

    a. Column lines, north arrow and graphical scale.
    b. Each pile identified by a separate number, designated by the CONTRACTOR and submitted prior to pile driving.
    c. Elevation of each top of pile prior to and after cutting, to the nearest 0.01 foot.
    d. Deviation in feet, to the nearest 0.01 foot, from plan design location at cutoff elevation.

1.07 PRODUCT DELIVERY, STORAGE AND HANDLING

A. The CONTRACTOR shall deliver piles at approved times and in sequence to assure continuity of pile driving.

B. Piles shall be handled, transported, stacked, and protected to prevent damage.

C. Lifting points shall be clearly marked on the piles by the manufacturer. Piles shall be lifted up into the leads at the designated lifting points.

D. Piles shall be clearly marked with the length of the pile prior to delivery.

1.08 LINES AND GRADES

A. The CONTRACTOR shall stake the pile locations and establish all elevations required. A baseline and benchmark located on or close to the site will be provided by the OWNER. The CONTRACTOR shall be responsible for the maintenance and protection of the baseline and benchmark, and all pile location stakes.

B. The CONTRACTOR shall employ a Land Surveyor licensed in the State of Maine, familiar with pile installation, who shall establish lines and levels. The CONTRACTOR shall be responsible for determining the location of piles, as well as keeping up to date records of the amount of uplift of individual piles, and establishing actual pile locations.

PART 2 - PRODUCTS

2.01 GENERAL

A. Pile materials shall be new and of uniform quality. Manufactured or assembled pile materials shall be of sufficient strength and rigidity to withstand all driving stresses.

B. Length of piles to be ordered shall be determined by the CONTRACTOR. Ordering, delivery and use of piles shall be planned and performed in such a manner that minimizes delays or interruption of driving and precludes the need for splices. Ordering and delivery of piles shall be planned in such a manner that changes in length for piles not yet manufactured may be made if driving experience, as work progresses, indicates need for such changes.

2.02 PRECAST-PRESTRESSED CONCRETE PILES

A. Piles shall be square precast-prestressed concrete piles with 16-inch (Parking Garage) and 14-inch (Office Building) minimum side dimensions. All precast concrete piles shall be designed, reinforced and manufactured in accordance with current standards of the Joint Committee of AASHTO and PCI. Hollow core piles will not be accepted.

B. Concrete for precast piles shall be Type V and shall have minimum compressive strength of 5,000 psi at 28 days. The maximum water/cement ratio shall not exceed 0.40. No precast concrete piles shall be delivered to the site before concrete has attained a compressive strength of 4,000 psi, based on tests of cylinders cast from same batches and cured under same conditions as pile concrete. Provide the GEOTECHNICAL ENGINEER with each delivery, documentation in acceptable form indicating that concrete used in piles had attained minimum compressive strength of 4,000 psi, prior to delivery of piles to site, and that the piles conform to PCI and AASHTO requirements. Pile materials shall also be subject to on-site inspection for

conformance with specifications. Regardless of concrete strength data, no piles shall be delivered to site until they are at least 48 hours old.

C. If, for any reason, a pile is damaged or reinforcing steel is exposed, its use shall not be allowed.

D. Lateral reinforcing at both ends of piles shall be spaced sufficiently close to resist impact stresses due to driving and in no case more than three (3) inches on center. Lateral reinforcing for piles shall also conform to the requirements of the IBC Code. Top of pile must be perpendicular to longitudinal axis of pile, and ends of any prestressing or reinforcing steel shall be cut flush with top of pile to prevent direct impact on steel during driving.

E. Precast piles shall be cast with a steel bottom plate. The plate shall have a minimum thickness of 1-1/2 inches, have the same lateral dimensions as the pile, and shall be attached to the pile with dowels as indicated in the AASHTO-PCI standards. Dowels shall extend into the pile a minimum distance of 30 inches.

F. Concrete for precast piles shall contain a maximum tricalcium aluminate (C3A) content of six (6) percent. Upon delivery of the piles to the site, provide the GEOTECHNICAL ENGINEER with certificates indicating that the tricalcium aluminate content conforms to this requirement.

H. Requirements for Pile Cap Seismic Connection: The CONTRACTOR shall consider the requirements outlined in the IBC Code when estimating anticipated pile lengths at each column location or other point of structure support to ensure that the minimum required length of reinforcement requirements in the upper portion of the pile is achieved in accordance with the seismic requirements of the IBC Code.

I. Reinforcing Steel

1. Reinforcing bars: ASTM A615, grade 60, deformed.
2. Spiral reinforcing for piles: ASTM A615, grade 60 plain bars, or ASTM A82 smooth wire, except that for wire with Fy over 60,000 psi, the Fy shall be the stress corresponding to strain of 0.35 percent.

2.03 SPLICES

A. Full length piles shall be used wherever practicable.

B. If full length piles cannot be used, only one splice per pile shall be allowed.

C. Splices, when required, shall develop one hundred percent of the pile strength in tension, compression, and in bending. Details of the splice shall be shown on the Shop Drawings. Splices may be made by the cement-dowel method. Mechanical splices may be accepted by the ENGINEER if the splice can transfer full pile strength in compression, tension, and bending.

D. The strength of all splices, in compression, tension, and bending, shall be equal to or greater than the ultimate capacities of the pile section.

E. Piles may be spliced in the leads. The sections of piles to be spliced shall be secured in alignment such that there is no eccentricity between the axes of the two spliced lengths, or angle between them, after the splice has been completed.

F. Precast-prestressed piles shall be spliced with Sure-Lock type splice, or approved equivalent developing 100 percent of the pile section strength.

G. Mechanical drive-fit splices shall not be used.

2.04 PILE TIP/DRIVING SHOE

A. Precast piles shall be cast with a steel bottom plate. The plate shall have a minimum thickness of 1-1/2 inches, have the same lateral dimensions as the pile, and shall be attached to the pile with dowels as indicated in the AASHTO-PCI standards. Dowels shall extend into the pile a minimum distance of 30 inches.

2.05 PILE LENGTH MARKINGS

A. Permanently mark the entire length of each pile with horizontal lines (perpendicular to long axis of pile) measured from the pile tip at 12-in. intervals. In addition, footage shall be marked and designated at 5-ft intervals, starting from the tip of the pile.

PART 3 - EXECUTION

3.01 SEQUENCE OF OPERATIONS AND EQUIPMENT REQUIREMENTS

A. The CONTRACTOR shall provide the necessary pile driving equipment for full-time operation at the site during the work to complete the work on schedule. The work shall require the mobilization of crane mounted equipment for installation of the indicator and production piles.

B. Prior to production pile installation, the CONTRACTOR shall drive indicator piles at production pile locations, at the locations shown on the Drawings. The CONTRACTOR'S Professional Engineer shall perform dynamic (PDA) testing during installation of each indicator pile to aid in estimating the required pile lengths and to evaluate hammer performance, acceptable driving stresses, and to confirm the final driving criteria based on the measured hammer energy transferred to the pile.

C. Production piles shall not be installed before the indicator piles are driven and results reviewed by the GEOTECHNICAL ENGINEER. Production piles installed prior to completion of the indicator pile program will be at the sole risk of the CONTRACTOR. The CONTRACTOR may elect to drive more than the required minimum number of indicator piles at the CONTRACTOR'S election if approved by the GEOTECHNICAL ENGINEER.

D. The CONTRACTOR shall coordinate their pile installation operations with other work on the site.

3.02 PILE DRIVING CRITERIA

A. The CONTRACTOR shall furnish and install precast, prestressed concrete piles to bedrock and to the approved final penetration resistance that will develop the required design compression capacity as specified herein.

B. The CONTRACTOR shall drive piles to not less than an approved final penetration resistance over the final 6 in. of driving as determined by the WEAP analyses and confirmed by the PDA testing unless directed by the GEOTECHNICAL ENGINEER.

C. To limit the potential for overstressing of the pile during driving, if less than 1/2 in. of penetration is achieved in 10 successive hammer blows, driving should be stopped and the pile shall be evaluated by the GEOTECHNICAL ENGINEER.

3.03 INDICATOR PILE INSTALLATION

A. Indicator piles shall be driven by the CONTRACTOR using the proposed production pile driving equipment to the final driving criteria identified herein and as supported by the CONTRACTOR'S approved WEAP analyses.

B. Indicator piles shall be driven at the locations shown on the plans.

C. Per the requirements of the IBC Code, no piles shall be driven or tested except in the presence of the GEOTECHNICAL ENGINEER.

D. The use of followers will not be permitted unless authorized in writing by the GEOTECHNICAL ENGINEER.

3.04 DYNAMIC PILE (PDA) TESTING

A. During driving of the indicator piles, the CONTRACTOR'S Professional Engineer shall conduct PDA testing on all indicator piles to evaluate the performance of the hammer-pile system(s), calculate stresses in the pile during driving, assess the structural integrity of the pile, and evaluate pile capacity/pile driving criteria. The CONTRACTOR'S Professional Engineer shall perform CAPWAP analyses on four of the piles as selected by the GEOTECHNICAL ENGINEER. Up to five indicator piles will be restruck between 24 and 48 hours after completion of driving as determined by the GEOTECHNICAL ENGINEER to assess "false driving resistance" and "setup" of the piles

B. The CONTRACTOR shall plan adequate time for PDA testing and CAPWAP analyses to be performed during driving of the indicator piles.

C. If based on the results of the PDA testing, the GEOTECHNICAL ENGINEER determines the hammer(s) is not working adequately; the hammer(s) will be repaired or replaced by the CONTRACTOR at no additional cost to the OWNER. In this instance, the CONTRACTOR shall redrive all previously driven piles and possibly additional indicator piles and repeat the dynamic testing, as required by the GEOTECHNICAL ENGINEER, at no additional cost to the OWNER.

D. If, at any time during production pile driving, the CONTRACTOR proposes to change the pile installation equipment (including the individual hammer or hammer type) from that used to install the indicator piles, PDA testing shall be performed by the CONTRACTOR'S Professional Engineer at the CONTRACTOR'S expense to confirm that the new hammer can transfer the minimum required energy to the pile and that pile stresses are within acceptable limits. Dynamic testing of a minimum of an additional 4 piles will be required in this case.

E. Depending on the results of the PDA testing the GEOTECHNICAL ENGINEER may adjust indicator pile locations and final driving criteria.

3.05 PRODUCTION PILE INSTALLATION

A. Piles shall be installed with approved modern equipment in good working order. The proposed pile installation equipment and methods shall be subject to approval of the GEOTECHNICAL ENGINEER and approval shall be secured before the start of installation.

B. The leads of the pile driving rig shall be fixed at two points; the points shall be at least half the length of the leads apart in order to maintain the pile and hammer in axial alignment at the correct

plan location during the entire driving operation. The leads shall extend down to the lowest point at which the hammer must operate.

C. At the CONTRACTOR'S option, an approved vibratory hammer may be used to install piles through overburden soils (i.e., fill, marine clay). If piles are initially installed using a vibratory hammer, impact driving to final bearing shall be completed within four hours of the completion of vibratory advance. Impact pile driving shall be continuous and without interruption for the final 10 ft of penetration.

D. Piles shall be driven with a single-acting, double-acting, or differential-acting steam, hydraulic, air, or diesel hammer(s) as approved based on the WEAP analyses, PDA testing and CAPWAP analyses. When the determination of the final driving resistance is being made, the steam, hydraulic, air or diesel hammer shall be operated at a speed not less than 95 percent of the maximum blows per minute for which the hammer is rated by the manufacturer. The CONTRACTOR shall maintain the boiler or air pressure recommended by the manufacturer and shall employ the proper size hose and connections. When the determination of final driving resistance is being made with a diesel hammer, the energy being delivered to the pile shall be determined as the product of the weight of the ram times the observed or equivalent stroke for open diesel hammers; for closed diesel hammers, the energy shall be that indicated by an output gauge calibrated to measure total hammer energy. The GEOTECHNICAL ENGINEER will monitor hammer performance of an open-ended diesel using a saximeter which measures the rate of hammer operation.

E. Special Requirement for Diesel Hammers: In the case of a diesel hammer, the CONTRACTOR shall provide an apparatus approved by the GEOTECHNICAL ENGINEER to measure gas pressures inside the hammer and total hammer energy for closed hammers, or ram bounce height in the case of open hammers.

F. An aluminum micarta cushion block or other cushion material consistent with WEAP analyses and PDA testing and if approved by the GEOTECHNICAL ENGINEER, shall be used in the hammer for driving piles. Cushions shall be replaced when burned or otherwise worn.

G. Hammers used to install production piles shall be the same physical equipment that was used to install the indicator piles.

H. The use of followers will not be permitted unless authorized in writing by the GEOTECHNICAL ENGINEER.

I. Piles that are unsatisfactory as installed shall be removed, or repaired at no additional cost to the Owner.

J. Pre-drilling:

1. If the CONTRACTOR elects to pre-drill it will be considered incidental to its work, at no additional cost to the OWNER.

K. Driving:

1. As part of preparation for driving, each pile shall be marked as specified herein.
2. Pile tips shall be protected as specified herein.
3. All piles shall be driven plumb/vertical at the locations and orientations shown on the plans. The CONTRACTOR shall utilize a pile alignment system such as templates or other measures to position the piles at the correct location. Pile location and orientation shall be

checked during driving and appropriate measures taken, as necessary, to maintain the correct pile position.

4. Each pile shall be driven to end-bearing into the bedrock (below the marine clay) to a minimum ultimate capacity (compression) of 360 tons (Parking Garage) and 280 tons (Office Building) using the accepted final pile driving criteria.
5. Pile driving shall be continuous and without interruption for the final 10 ft of penetration. If pile driving is interrupted during the final 10 ft of driving, the GEOTECHNICAL ENGINEER shall be the sole judge of whether the pile driving resistance is impacted by frictional resistance above the bearing stratum. Pile driving shall be terminated when the accepted final pile driving criteria is achieved or when pile penetration is less than 1/2 inch in 10 successive blows in the bearing stratum.
6. Pile driving resistance shall be constant or increasing during achievement of the final driving criteria.
7. During pile driving, the maximum compressive and tensile stress in the piles shall not exceed the maximum allowable compressive and tensile strength of the concrete in accordance with the IBC Code (Section 1808).
8. When driving piles through soft soils or in pre-drilled holes, the hammer ram velocity at impact shall be reduced to avoid damage of the pile due to tensile stresses in the piles.
9. Immediately after a pile in a pile group is driven, and prior to driving another pile within the piles' radius of uplift, the CONTRACTOR will establish a reference point and its elevation on the pile for the purpose of checking uplift (heave) of the pile as additional piles are driven.
10. After all piles within the radius of uplift have been driven, the CONTRACTOR shall determine the elevation of the reference points on each of the piles in the group. If uplift of 0.04 feet or more has occurred, the pile shall be redriven to its original elevation, and deeper if necessary, to the accepted final pile driving criteria. After redriving each pile, the CONTRACTOR will re-establish the elevation of the reference point. Redriving shall be repeated as often as necessary until the measured uplift on any pile is less than 0.04 ft.
11. The radius of uplift shall be initially assumed to be 30 ft. This radius may be expanded or contracted by the GEOTECHNICAL ENGINEER based on actual field measurements and is defined as the maximum distance between piles such that pile driving causes uplift of 0.04 feet or more in the affected pile.
12. Piles in a group shall be driven commencing in the center of the group and working toward the edge. All piles in any one group shall be driven before moving to other locations, unless otherwise acceptable to the GEOTECHNICAL ENGINEER.

L. Vibration Control:

1. Limit pile-driving induced ground vibrations (maximum peak particle velocity) to less than the values provided below at all nearby fresh concrete, as measured by the GEOTECHNICAL ENGINEER.

Concrete Age (days)	Maximum Peak Particle Velocity (in./sec)
0 to 1 day old	0.5
1 to 7 days old	2.0
Greater than 7 days old	3.0

2. If pile-driving induced vibrations exceed the level specified above, the CONTRACTOR shall adapt and modify pile driving procedures and equipment to limit vibrations below the specified level, at no additional cost to the OWNER.
3. Vibration monitoring will be performed by the GEOTECHNICAL ENGINEER as necessary to determine compliance with this criterion.

M. Cutting Off Piles:

1. Pile tops shall be cut off square and within 1 in. of the elevations shown on the Drawings. The pile cut-offs shall be stockpiled in a designated area of the site and shall be removed from the site by the CONTRACTOR at no additional cost to the OWNER.
2. If piles are driven below the design elevation and can not be satisfactorily built-up in the opinion of the STRUCTURAL and GEOTECHNICAL ENGINEERS, these piles shall be cutoff a minimum of 1 ft below the design bottom of the pile cap and abandoned at no cost to the OWNER. Additional piles required to compensate for an abandoned pile shall be driven as directed by the GEOTECHNICAL and STRUCTURAL ENGINEERS, at no additional cost to the OWNER.
3. Prepare all pile types to receive connection to pile cap and/or floor slab.

3.06 SPLICING

A. A maximum of one splice per pile will be permitted using the splicing system approved by the ENGINEER and the methods recommended by the Manufacturer. Splices shall develop one hundred percent of the pile strength in tension, compression and bending.

B. Pile splices shall be located so as to permit continuous driving through the bearing stratum and to final end bearing.

C. The strength of all splices, in compression, tension, and bending, shall be equal to or greater than the ultimate capacities of the pile section.

D. Piles may be spliced in the leads. The sections of piles to be spliced shall be secured in alignment such that there is no eccentricity between the axes of the two spliced lengths, or angle between them, after the splice has been completed.

E. Unless waived by the ENGINEER, the CONTRACTOR shall proof test the proposed splice. Splicing and testing shall be done in the presence of the ENGINEER. Testing shall be completed, to the satisfaction of the ENGINEER, during production pile driving. A minimum of six tests shall be conducted, consisting of a minimum of two tests each in compression, tension and bending. Tests shall be conducted on full scale splices, which are constructed in a manner identical to that proposed for use on the project. Tests shall be conducted using calibrated equipment to monitor load and deflection. The CONTRACTOR shall take all measurements and submit results of the tests to the ENGINEER. Tests results shall include calculations based on the test data, of the capacity of the splice in compression, tension and bending made by a Professional Engineer licensed in the State of Maine. The splice will be approved provided that at least two tests each in compression, tension and bending demonstrate that the capacity of the proposed splice is equal to or greater than the ultimate capacity of the pile. Prior to the start of testing, the CONTRACTOR shall submit the proposed proof testing methods to the ENGINEER for review and approval.

3.07 TOLERANCES AND CRITERIA FOR ACCEPTANCE

A. Location: Piles shall be driven as close as practicable to the plan location. A maximum permissible lateral deviation from the design location measured in any direction at cut-off elevation will be 1.5 inches for single piles and groups of two piles, and 3 inches for each pile within groups of three (3) or more piles. A maximum deviation from design cut-off elevation equal to 1 in. will be permitted.

B. Plumbness: The pile plumbness, as measured on the projection of the pile above ground, shall not deviate by greater than ten percent from the vertical alignment. Pulling piles into alignment or position will not be permitted.

C. Piles that are damaged below cut-off elevation during driving will be rejected. If, upon comparing pile performance during driving with that of other driven piles, and based on the GEOTECHNICAL ENGINEER'S knowledge of subsurface conditions, the GEOTECHNICAL ENGINEER determines that a pile has been unacceptably damaged; the GEOTECHNICAL ENGINEER may reject the pile.

D. Piles indicating sudden or peculiar decrease in penetration resistance during driving will be assumed to be broken or damaged, and will be rejected unless the GEOTECHNICAL ENGINEER'S review of available data indicates that sudden decrease in driving resistance is due to natural subsurface conditions and continued acceptable driving behavior is observed.

E. Piles that are rejected because of damage, mislocation or misalignment, or failure to meet the driving criteria due to causes other than obstructions as defined herein, shall be cut off a minimum of 1 ft below the design bottom of the pile cap and abandoned, and additional piles shall be driven as directed by the GEOTECHNICAL ENGINEER at no additional cost to the OWNER.

F. When otherwise acceptable installed piles exceed the specified location and/or plumbness tolerances, the STRUCTURAL ENGINEERS will analytically determine the total loads on individual piles, based on a survey by the CONTRACTOR'S Land Surveyor. If the load on any pile exceeds 110 percent of the specified load capacity, corrections shall be made by adding piles, or other procedures, in accordance with a design provided by the STRUCTURAL ENGINEER.

G. The installation of replacement piles and other corrective measures shall in all cases be in accordance with designs provided by the STRUCTURAL ENGINEER.

H. Any increased costs for redesign and for construction caused by rejected piles or piles exceeding tolerances not caused by obstructions shall be the responsibility of the CONTRACTOR.

I. Vibration levels will be monitored as necessary by the GEOTECHNICAL ENGINEER during pile driving.

End of Section