ATTACHMENT –L

WMATA SPECIAL PROVISIONS FOR SP006-SECTION 02465

HELICAL SCREW FOUNDATIONS

September 20, 2019

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY
SPECIAL PROVISION FOR

SP006 – SECTION 02465
HELICAL SCREW FOUNDATIONS

PART 1 – GENERAL

1.1 Purpose of Specification

The purpose of this specification is to detail the furnishing of all designs, materials, tools, equipment, labor and supervision, and installation techniques necessary to install HELICAL SCREW FOUNDATIONS (HSF), also known as helical piles, as detailed on the drawings, including connection details. This shall include provisions for load testing that may be part of the scope of work

1.2 Scope of Work

This work consists of furnishing all necessary, supervision, labor, tools, materials, and equipment to perform all work necessary to install the HELICAL SCREW FOUNDATIONS as per the specifications described herein, and as shown on the drawings. The Contractor shall install a helical screw foundation that will develop the load capacities as detailed on the drawings.

1.3 Qualifications of the Helical Screw Foundation Contractor

The HSF Contractor shall be experienced in performing design and construction of helical screw foundations and shall furnish all materials, labor, and supervision to perform the work. The Contractor shall be certified by the manufacturer and/or their authorized representatives in the proper methods of design and installation of helical screw foundations.

The HSF Contractor shall not sublet the whole or any part of the contract without the express written permission of the Owner.

1.4 Allowable Tolerances

1.4.1 Centerline of helical screw foundations shall not be more than 3 inches from indicated plan location.

1.4.2 Helical screw foundation plumbness shall be within 5° of design alignment.

1.4.3 Top elevation of helical screw foundation shall be within +1 inch to –2 inches of the design vertical elevation.

1.5 Quality Assurance

1.5.1 Helical screw foundations shall be installed by a contractor certified by the manufacturer and/or their authorized representatives.

1.5.2 The Contractor shall employ an adequate number of skilled workers who are experienced in the necessary crafts and who are familiar with the specified requirements and methods needed for proper performance of the work of this specification.

1.5.3 All HSFs shall be installed in the presence of a designated representative of the Owner unless said representative informs the Contractor otherwise. The designated representative shall have the right to access to any and all field installation records and test reports.

1.5.4 Screw foundation components as specified therein shall be manufactured by a facility whose quality systems comply with ISO (International Organization of Standards) 9001 requirements. Certificates of Registration denoting ISO Standards Number shall be presented upon request to the Owner or their representative.

1.6 Ground Conditions

The Geotechnical Report(s), including logs of soil borings as shown on the boring location plan, shall be considered to representative of the in-situ subsurface conditions likely to be encountered on the project site. As required for the design, additional subsurface investigations shall be performed and documented in a supplementary geotechnical report. These Geotechnical Report(s) shall be used as the basis for helical screw foundation design using generally accepted engineering judgement and methods.

2 REFERENCED CODES AND STANDARDS

Standards listed by reference, including revisions by issuing authority, form a part of this specification section to the extent indicated. In case of conflict, the particular requirements of this specification shall prevail. The latest publication as of the issue of this specification shall govern, unless indicated otherwise.

2.1 American Society for Testing and Materials (ASTM):

2.1.1 ASTM A29/A29M Steel Bars, Carbon and Alloy, Hot-Wrought and Cold Finished.
2.1.2 ASTM A36/A36M Structural Steel.
2.1.3 ASTM A53 Pipe, Steel, Black and Hot-Dipped, Zinc-Coated Welded and Seamless.
2.1.4 ASTM A153 Zinc Coating (Hot Dip) on Iron and Steel Hardware.
2.1.5 ASTM A252 Welded and Seamless Steel Pipe Piles.
2.1.6 ASTM A775 Electrostatic Epoxy Coating
2.1.7 ASTM A193/A193M Alloy-Steel and Stainless Steel Bolting Materials for High Temperature Service.
2.1.8 ASTM A320/A320M Alloy-Steel Bolting Materials for Low Temperature Service.
2.1.9 ASTM A500 Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes.
2.1.10 ASTM A572 HSLA Columbium-Vanadium Steels of Structural Quality.
2.1.11 ASTM A618 Hot-Formed Welded and Seamless High-Strength Low-Alloy Structural Tubing.
2.1.12 ASTM A656 Hot-Rolled Structural Steel, High-Strength Low-Alloy Plate with Improved Formability.
2.1.13 ASTM A1018 Steel, Sheet and Strip, Heavy Thickness Coils, Hot Rolled, Carbon, Structural, High-Strength Low-Alloy, Columbium or Vanadium, and High-Strength Low-Alloy with Improved Formability.
2.1.14 ASTM D1143 Method of Testing Piles Under Static Axial Compressive Load.
2.1.15 ASTM D3689 Method of Testing Individual Piles Under Static Axial Tensile Load.

2.2 American Welding Society (AWS):

2.2.1 AWS D1.1 Structural Welding Code – Steel.
2.2.2 AWS D1.2 Structural Welding Code – Reinforcing Steel.

2.3 American Society of Civil Engineers (ASCE):

2.3.1 ASCE 20-96 Standard Guidelines for the Design and Installation of Pile Foundations.

2.4 Deep Foundations Institute (DFI):

2.4.1 *Guide to Drafting a Specification for High Capacity Drilled and Grouted Micropiles for Structural Support*, 1st Edition, Copyright 2001 by the Deep Foundation Institute (DFI).

2.5 Post Tensioning Institute (PTI):

2.5.1 *Recommendations for Prestressed Rock and Soil Anchors*, Third Edition, Copyright 1996 By the Post-Tensioning Institute.

2.6 Society of Automotive Engineers (SAE):

2.6.1 SAE J429 Mechanical and Material Requirements for Externally Threaded Fasteners.

3 SUBMITTALS

3.1 Construction Submittals

3.1.1 The Contractor shall submit a detailed description of the construction procedures proposed for use to the Owner for review. This shall include a list of major equipment to be used.

3.1.2 The technical submittal shall include the following:

3.1.2.a Helical Screw Foundation number, location and pattern by assigned identification number
3.1.2.b HSF design load
3.1.2.c Type and size of central steel shaft
3.1.2.d Helix configuration (number and diameter of helix plates)
3.1.2.e Minimum effective installation torque
3.1.2.f HSF attachment to structure relative to grade beam, column pad, pile cap, etc.

3.1.3 The Contractor shall submit shop drawings for all HSF components including pile top attachment to the Owner for review and approval. This includes HSF lead and extension section identification (manufacturer's catalog numbers).

3.1.4 Work shall not begin until all the submittals have been received and approved by the Owner.

3.1A Design Requirements

The design of the HSF shall conform to Acceptance Criteria AC358, including the allowable axial load per Section 1810.3.3.1.9 of the 2012 IBC. The contractor shall submit all design calculations to the Owner for review and approval.

3.2 Installation Records

The Contractor shall provide the Owner copies of HSF installation records within 24 hours after each installation is completed. Formal copies shall be submitted on a weekly basis. These installation records shall include, but are not limited to, the following information.

3.2.1 Name of project and Contractor
3.2.2 Name of Contractor's supervisor during installation
3.2.3 Date and time of installation
3.2.4 Name and model of installation equipment
3.2.5 Type of torque indicator used
3.2.6 Location of HSF by assigned identification number
3.2.7 Actual HSF type and configuration – including lead section (number and size of helix plates), number and type of extension sections (manufacturer's SKU numbers)
3.2.8 HSF installation duration and observations
3.2.9 Total length of installed HSF

3.2.10 Cut-off elevation
3.2.11 Inclination of HSF
3.2.12 Installation torque at one-foot intervals for the final 10 feet
3.2.13 Comments pertaining to interruptions, obstructions, or other relevant information
3.2.14 Rated load capacities

4 PRODUCTS AND MATERIALS

4.1 Central Steel Shaft:

The central steel shaft, consisting of lead sections, helical extensions, and plain extensions, shall be Type SS or HS or a combination of the two (SS to HS Combo Pile) as manufactured by the A. B. Chance Company (Centralia, MO), or approved equal.

4.1.1 *SS5 1-1/2" Material*: Shall be hot rolled Round-Cornered-Square (RCS) solid steel bars meeting dimensional and workmanship requirements of ASTM A29. The bar shall be modified medium carbon steel grade (similar to AISI 1044) with improved strength due to fine grain size.

4.1.1.a Torsional strength rating = 5,500 ft-lb
4.1.1.b Minimum yield strength = 70 ksi

4.1.2 *SS150 1-1/2"; SS175 1-3/4; SS200 2"; SS225 2-1/4" Material*: Shall be hot rolled Round-Cornered-Square (RCS) solid steel bars meeting the dimensional and workmanship requirements of ASTM A29. The bar shall be High Strength Low Alloy (HSLA), low to medium carbon steel grade with improved strength due to fine grain size.

4.1.2.a Torsional strength rating: SS150 = 7,000 ft-lb; SS175 = 10,000 ft-lb; SS200 = 15,000 ft-lb; SS225 = 20,000 ft-lb
4.1.2.b Minimum yield strength = 90 ksi

4.1.3 *HS 3-1/2" OD Material*: Shall be structural steel tube or pipe, seamless or straight-seam welded, per ASTM A53, A252, ASTM A500, or ASTM A618. Wall thickness is 0.300" (schedule 80).

4.1.3.a Torsional strength rating = 11,000 ft-lb
4.1.3.b Minimum yield strength = 50 ksi

4.1.4 *Type RS2875 2-7/8" OD Material*: Structural steel tube or pipe, welded or seamless, in compliance with ASTM A500 or A513. Wall thickness is 0.165", 0.203" or 0.262".

4.1.4.a Torque strength rating: RS2875.165 = 4,500 ft-lb; RS2875.203 = 5,500 ft-lb; RS2875.262 = 7,500 ft-lb.
Minimum yield strength = 50 ksi

4.1.5 *SS to HS Combo Pile Material*: Shall be Type SS and HS material as described above with a welded adapter for the transition from SS to HS.

4.2 Helix Bearing Plate:

Shall be hot rolled carbon steel sheet, strip, or plate formed on matching metal dies to true helical shape and uniform pitch. Bearing plate material shall conform to the following ASTM specifications.

4.2.1 *SS5 Material*: Per ASTM A572, or A1018, or A656 with minimum yield strength of 50 ksi. Plate thickness is 3/8".
4.2.2 *SS150 and SS175 Material*: Per ASTM A656 or A1018 with minimum yield strength of 80 ksi. Plate thickness is 3/8".

4.2.3 *SS200 and SS225 Material*: Per ASTM A656 or A1018 with minimum yield strength of 80 ksi. Plate thickness is ½".
4.2.4 *HS Material*: Per ASTM A36, or A572, or A1018, or A656 depending on helix diameter, per the minimum yield strength requirements cited above. Plate thickness is 3/8".
4.2.5 *RS2875 Material*: Per ASTM A36, or A572, with minimum yield strength of 36 ksi. Plate thickness is 3/8" or ½".

4.3 Bolts:

The size and type of bolts used to connect the central steel shaft sections together shall conform to the following ASTM specifications.

4.3.1 *SS5 and SS150 1-1/2" Material*: 3/4" diameter bolt per ASTM A320 Grade L7.
4.3.2 *SS175 1-3/4" Material*: 7/8" diameter bolt per ASTM A193 Grade B7.
4.3.3 *SS200 2" Material*: 1-1/8" diameter bolt per ASTM A193 Grade B7.
4.3.4 *SS225 2-1/4" Material*: 1-1/4" diameter bolt per ASTM A193 Grade B7.
4.3.5 *HS 3-1/2" OD Material*: ¾" diameter bolts (3 per coupling) per SAE J429 Grade 5.
4.3.6
RS2875 2-7/8" OD Material: ¾" diameter bolts (2 or 4 per coupling) per SAE J429 Grade 5 or 8.

4.4 Couplings:

Shall be formed as integral part of the plain and helical extension material. For Type HS material, the couplings shall be hot forge expanded sockets.

4.5 Plates, Shapes, or Pier Caps:

Structural steel plates and shapes for HSF top attachments shall conform to ASTM A36 or ASTM A572 Grade 50.

4.6 Corrosion Protection

4.6.1 Galvanization: All A. B. Chance Type HS material shall be hot-dipped galvanized in accordance with ASTM A123 after fabrication.

5 EXECUTION

5.1 Site Conditions

5.1.1 Prior to commencing helical screw foundation installation, the Contractor shall inspect the work of all other trades and verify that all said work is completed to the point where HSFs may commence without restriction.

5.1.2 The Contractor shall verify that all HSFs may be installed in accordance with all pertinent codes and regulations regarding such items as underground obstructions, right-of-way limitations, utilities, etc.

5.1.3 In the event of a discrepancy, the Contractor shall notify the Owner. The Contractor shall not proceed with HSF installation in areas of discrepancies until said discrepancies have been resolved. All costs associated with unresolved discrepancies shall be the responsibility of the Owner.

5.2 Installation Equipment

5.2.1 Shall be rotary type, hydraulic power driven torque motor with clockwise and counter-clockwise rotation capabilities. The torque motor shall be capable of continuous adjustment to revolutions per minute (RPM's) during installation. Percussion drilling equipment shall not be permitted. The torque motor shall have torque capacity 15% greater than the torsional strength rating of the central steel shaft to be installed.

5.2.2 Equipment shall be capable of applying adequate down pressure (crowd) and torque simultaneously to suit project soil conditions and load requirements. The equipment shall be capable of continuous position adjustment to maintain proper HSF alignment.

5.3 Installation Tooling

5.3.1 Shall consist of a Kelly Bar Adapter (KBA) and Type SS or HS drive tool as manufactured by A. B. Chance Company, or approved equal, and used in accordance with the manufacturers written installation instructions.

5.3.2 A torque indicator shall be used during HSF installation. The torque indicator can be an integral part of the installation equipment or externally mounted in-line with the installation tooling.

5.3.2.a Shall be capable of providing continuous measurement of applied torque throughout the installation.

5.3.2.b Shall be capable of torque measurements in increments of at most 500 ft-lb

5.3.2.c Shall be calibrated prior to pre-production testing or start of work. Torque indicators which are an integral part of the installation equipment, shall be calibrated on-site. Indicators that measure torque as a function of hydraulic pressure shall be calibrated at normal operating temperatures. Prior to installation, the contractor shall submit testing and calibration certificates for torque indicator equipment to be used.

5.3.2.d Shall be re-calibrated, if in the opinion of the Owner and/or Contractor reasonable doubt exists as to the accuracy of the torque measurements.

5.4 Installation Procedures

5.4.1 *Central Steel Shaft: (Lead and Extension Sections)*

5.4.1.a The HSF installation technique shall be such that it is consistent with the geotechnical, logistical, environmental, and load carrying conditions of the project.

5.4.1.b The lead section shall be positioned at the location as shown on the working drawings. Battered HSFs can be positioned perpendicular to the ground to assist in initial advancement into the soil before the required batter angle shall be established. The HSF sections shall be engaged and advanced into the soil in a smooth, continuous manner at a rate of rotation of 5 to 20 RPM's. Extension sections shall be provided to obtain the required minimum overall length and installation torque as shown on the working drawings. Connect sections together using coupling bolt(s) and nut torqued to 40 ft-lb.

5.4.1.c Sufficient down pressure shall be applied to uniformly advance the HSF sections approximately 3 inches per revolution. The rate of rotation and magnitude of down pressure shall be adjusted for different soil conditions and depths.

5.5 Termination Criteria

5.5.1 The torque as measured during the installation shall not exceed the torsional strength rating of the central steel shaft.

5.5.2 The minimum installation torque, minimum overall length criteria, or suitable bearing (helix not advancing with proper downpressure) as shown on the technical submittal shall be satisfied prior to terminating the helical screw foundation installation.

5.5.3 If the torsional strength rating of the central steel shaft and/or installation equipment has been reached prior to achieving the minimum overall length required, the Contractor shall have the following options:

5.5.3.a Terminate the installation at the depth obtained subject to the review and acceptance of the Owner, or:

5.5.3.b Remove the existing HSF and install a new one with fewer and/or smaller diameter helix plates. The new helix configuration shall be subject to review and acceptance of the Owner. If re-installing in the same location, the top-most helix of the new HSF shall be terminated at least (3) three feet beyond the terminating depth of the original HSF.

5.5.4 If the minimum installation torque as shown on the working drawings is not achieved at the minimum overall length, and there is no maximum length constraint, the Contractor shall have the following options:

5.5.4.a Install the HSF deeper using additional extension sections, or:

5.5.4.b Remove the existing HSF and install a new one with additional and/or larger diameter helix plates. The new helix configuration shall be subject to review and acceptance of the Owner. If re-installing in the same location, the top-most helix of the new HSF shall be terminated at least (3) three feet beyond the terminating depth of the original HSF.

5.5.4.c De-rate the load capacity of the HSF and install additional helical screw foundation(s). The de-rated capacity and additional helical screw foundation location shall be subject to the review and acceptance of the Owner.

5.5.5 If the HSF is refused or deflected by a subsurface obstruction, the installation shall be terminated and the pile removed. The obstruction shall be removed, if feasible, and the HSF re-installed. If the obstruction can't be removed, the HSF shall be installed at an adjacent location, subject to review and acceptance of the Owner.

5.5.6 If the torsional strength rating of the central steel shaft and/or installation equipment has been reached prior to proper positioning of the last plain extension section relative to the final elevation, the Contractor may remove the last plain extension and replace it with a shorter length extension. If it is not feasible to remove the last plain extension, the Contractor may cut said extension shaft to the correct elevation. The Contractor shall not reverse (back-out) the helical screw foundation to facilitate extension removal.

5.5.7 The average torque for the last three feet of penetration shall be used as the basis of comparison with the minimum installation torque as shown on the working drawings. The average torque shall be defined as the average of the last three readings recorded at one-foot intervals.

6 HELICAL SCREW FOUNDATION LOAD TESTS

6.1 Use the ASTM D1143A Section 8.1.2 "Quick Load"

6.2 Load Test Equipment

6.2.1 The load test equipment shall be capable of increasing or decreasing the applied load incrementally. The incremental control shall allow for small adjustments, which may be necessary to maintain the applied load for a sustained, hold period.

6.2.2 The reaction system shall be designed so as to have sufficient strength and capacity to distribute the test loads to the ground. It should also be designed to minimize its movement under load and to prevent applying an eccentric load to the pile head. Test loads are normally higher than the design loads on the structure. The direction of the applied load shall be collinear with the HSF at all times.

6.2.3 Dial gauge(s) shall be used to measure HSF movement. The dial gauge shall have an accuracy of at least +/-0.001-in. and a minimum travel sufficient to measure all HSF movements without requiring resetting the gauge. The dial gauge shall be positioned so its stem is parallel with the axis of the HSF. The stem may rest on a smooth plate located at the pile head. Said plate shall be positioned perpendicular to the axis of the HSF. The dial gauge shall be supported by a reference apparatus to provide an independent fixed reference point. Said reference apparatus shall be independent of the reaction system and shall not be affected by any movement of the reaction system.

6.2.4 The load test equipment shall be re-calibrated, if in the opinion of the Owner and/or Contractor reasonable doubt exists as to the accuracy of the load or deflection measurements.

6.3 Testing Program

6.3.1 Prior to testing, the contractor shall submit testing and calibration certificates for the hydraulic jacks to be used. The hydraulic jack shall be positioned at the beginning of the test such that the unloading and repositioning of the jack during the test shall not be required. The jack shall also be positioned co-axial with respect to the pile-head so as to minimize eccentric loading. The hydraulic jack shall be capable of applying a load not less than two times the proposed design load (DL). The pressure gauge shall be graduated in 100 psi increments or less. The stroke of the jack shall not be less than the theoretical elastic shortening of the total HSF length at the maximum test load.

6.3.2 An alignment load (AL) shall be applied to the HSF prior to setting the deflection measuring equipment to zero or a reference position. The AL shall be no more than 10% of the design load (i.e., 0.1 DL). After AL is applied, the test set-up shall be inspected carefully to ensure it is safe to proceed.

6.3.3 Axial compression or tension load tests shall be conducted by loading the HSF in step-wise fashion as shown in Table-3 to the extent practical. Pile-head deflection shall be recorded at the beginning of each step and after the end of the hold time. The beginning of the hold time shall be defined as the moment when the load equipment achieves the required load step.

6.3.4 Test loads shall be applied until continuous jacking is required to maintain the load step or until the test load increment equals 200% of the design load (DL) (i.e., 2.0 DL), whichever occurs first. The observation period for this last load increment shall be 10 minutes. Displacement readings shall be recorded at 1, 2, 3, 4, 5 and 10 minutes (load increment maxima only).

6.3.5 The applied test load shall be per ASTM D1143 Procedure a, Quick Test.

6.4 Acceptance Criteria for HSF Verification Load Tests

Both of the following criteria must be met for approval:

1. The HSF shall sustain the compression and tension design capacities (1.0 DL) with total vertical movement of the pile-head, as measured relative to the top of the HSF prior to the start of testing, not to exceed the maximum allowable as determined by the design engineer.
2. Failure does not occur at the 2.0 DL maximum compression and tension test loads. The failure load shall be defined by one of the following definitions – whichever results in the lesser load:

The Contractor shall provide the Owner copies of field test reports confirming HSF configuration and construction details within 24 hours after completion of the load tests. Formal copies shall be submitted as per Section 3.3. This written documentation will either confirm the load capacity as required on the working drawings or propose changes based upon the results of the pre-production tests.

When a HSF fails to meet the acceptance criteria, modifications shall be made to the design, the construction procedures, or both. These modifications include, but are not limited to, de-rating the HSF load capacity, modifying the installation methods and equipment, increasing the minimum effective installation torque, changing the helix configuration, or changing the HSF material (i.e., central steel shaft). Modifications that require changes to the structure shall have prior review and acceptance of the Owner. The cause for any modifications of design or construction procedures shall be decided in order to determine any additional cost implications.

END OF SPECIFICATION

APPENDIX

TABLE-1

MECHANICAL STRENGTH RATINGS – HELICAL SCREW FOUNDATIONS

RATING TYPE	CENTRAL STEEL SHAFT FAMILY					
	SS5 1-1/2" RCS	SS150 1-1/2" RCS	SS175 1-3/4" RCS	SS200 2" RCS	SS225 2-1/4" RCS	HS 3-1/2" O.D Pipe
Torsional Strength Rating (ft-lb)	5,500	7,000	10,000	15,000	20,000	11,000
Ultimate Capacity Per Helix (kip) (Tension/Compression)	*40	*40	*50	60	60	50
Allowable Capacity Per Helix w/ 2.0 Safety Factor (kip) (Tension/Compression)	20	20	25	30	30	25
Ultimate Tension Capacity for Axially Loaded Pile (kip)	70	70	100	150	200	100

*** For 14" Dia. Helix Plates, Reduce the Ultimate Capacity by 20%**

NOTE: Actual installed capacities are dependent on existing soil conditions.

TABLE-1B

MECHANICAL STRENGTH RATINGS – Type RS HELICAL PILES

RATING TYPE	CENTRAL STEEL SHAFT PRODUCT FAMILY				
	RS2875.165 2-7/8" OD Pipe Shaft	RS2875.203 2-7/8" OD Pipe Shaft	RS2875.262 2-7/8" OD Pipe Shaft	RS3500.300 2-7/8" OD Pipe Shaft	RS4500.337 4-1/2" OD Pipe Shaft
Torque Strength Rating (ft-lb)	4,500	5,500	7,500	13,000	23,000
Ultimate Strength Per Helix (kip) (Tension/Compression)	*40	*40	*40	50	60
Uplift/Compression Capacity Limit[1] (kip)	36	44	60	91	138
Ultimate Tension Strength[2] (kip)	50	60	100	120	140

*** For 14" Dia. 3/8" Thick Helix Plates, Reduce the Ultimate Capacity by 20%**

1 - Based on torque rating – Uplift/Compression Capacity Limit = Torque Rating x Kt

"Default" Kt for Type RS2875 Series = 8, for Type RS3500.300 = 7, for Type RS4500.337 = 6

SP007 - SECTION 02460

PILES

PART 1 - GENERAL

1.01 DESCRIPTION:

A. This section specifies furnishing and installing bearing piles, performance of Static Pile Load Tests ~~and Dynamic Pile Testing.~~

1. Sequence of Work:
   a. Conduct initial wave equation analysis, prepare Indicator Pile Order List and submit information to Engineer for review.
   b. Piles shall not be driven until embankments or excavations shown have been completed to the specified grade.
   ~~c. Obtain and drive the indicator piles where shown on the drawings. During initial driving perform Dynamic Pile Testing and the refined wave equation analysis on each indicator pile to confirm the length, and control blow count. Determine pile driving criteria on the basis of the pile driving analysis (PDA) during the initial driving and the static load test. Incorporate results into driving of subsequent indicator piles.~~
   d. Perform Static Pile Load Tests per Article 3.02.B.2 on indicator piles designated by the Engineer after all indicator piles have been installed. ~~After Static Load Test is complete immediately restrike all indicator piles with Dynamic Testing Apparatus installed and functioning.~~
   e. Analyze Static Pile Load Tests and evaluate data collected from Dynamic Pile Testing and refined wave equation analyses to determine pile driving criteria as indicated in item c.. Develop and submit the proposed "Order List" for production piles to the Engineer for approval.
   f. Order and procure production piles based on the approved "Order List".
   ~~g. Drive each production pile to twice the pile design load and "production maximum tip elevation", and report all data as specified to evaluate the adequacy of the foundation system.~~

B. Definitions:
1. Pile Group: All piles to support a foundation element or column within a specified area, or all piles to support a linear unit of retaining wall. Pile groups are shown on the Contract Drawings.
2. Production Piles: All piles ~~that are driven~~ after the installation of required test piles in accordance with the contract documents and which upon approval by the Engineer, become part of the permanent structure.
3. Indicator Pile: Indicator piles are shown on the Contract Drawings. ~~These piles shall be tested with the Dynamic Testing Apparatus.~~ Static load tests shall be conducted on the indicator piles shown on the Contract Drawings or as directed by the Engineer. The Engineer may direct that additional indicator piles be driven and that dynamic or static testing be conducted on them to verify the load capacity.
4. Reaction Piles: Piles driven by the Contractor to provide reaction for Static Pile Load Tests.

5. Predicted Maximum Tip Elevation: The elevation below which indicator pile tips must penetrate by at least one foot.
6. Production Maximum Tip Elevation: The elevation below which production pile tips must penetrate by at least one foot, based on the indicator pile test program.
7. Pile Design Load: The load each pile is designed to carry.
8. Ultimate Bearing Capacity: The maximum bearing capacity that the pile can sustain without rapid progressive settlement of the pile under constant load.

C. Pile Type:
~~1. Prestressed precast concrete piles, driven.~~

D. Related Information:
1. Grading, Excavating, and Backfilling: Section 02320.
2. Support of Excavation: Section 02260.
3. Concrete Formwork: Section 03100.
4. Concrete Reinforcement: Section 03200.
5. Cast-in-Place Structural Concrete: Section 03300.
~~6. Structural Precast Concrete: Section 03400.~~
~~7. Prestressed Concrete: Section 03415.~~

1.02 QUALITY ASSURANCE:

A. Codes, Regulations, Reference Standards and Specifications:
1. Codes and regulations of the jurisdictional authorities.
2. ASTM Standards:
a. D1143 - Test Method for Piles Under Static Axial Compressive Load.
~~b. D4945 - Test Method for High Strain Dynamic Testing of Piles.~~

1.03 SUBMITTALS:

A. Submit the following for the Engineer's approval in accordance with the General Requirements and with the additional requirements as specified for each:
1. Shop Drawings:
a. For Static Pile Load Tests, provide drawings that show load test apparatus setup including the method of applying the load. Drawings must show devices to be used to measure pile top movement.
~~b. For Dynamic Pile Testing, provide manufacturer's or vendor's data on transducers, computer, wiring, and schematic drawings for testing specified piles.~~
c. For Static Pile Load Test ~~and Dynamic Pile Testing programs,~~ provide detailed sequence of testing, evaluation of results and planned reports.
~~d. Pile splicing is not desired and shall be avoided. In the event that concrete piles are driven below the elevation of bottom of cap, build-ups, precast or cast-in-place splicing may be used when approved by the Engineer. The pile submittal shall include splice details, build-up details and any other details necessary to satisfy the requirements of these specifications.~~

e. The pile submittal shall show ~~prestressing methods, tendon arrangement,~~ working stresses, and methods for pick-up and handling of piles.

f. Submit certification of accuracy for all gauges and test equipment.

2. Documentation:

~~a. Driving Equipment/Accessories List:~~

~~1) Submit details of proposed driving equipment to include cranes, leads, hammer, compressors, powerpacks, driving caps, hammer cushions and pile cushions. Data on hammer shall include as a minimum the manufacturer's model number, estimate of efficiency, energy ratings and ram details, including operation certification performed within the last 90 days.~~

~~2) Submit details of accessory equipment to be used including service cranes, hoses, throttles, and pile handling rigging.~~

~~b. Submit procedures and details for installation of reinforcement and prestressing.~~

~~c. Submit materials certifications and concrete mix designs for all concrete products to be used during the pile installation.~~

d. Indicator Pile Order List:

1) Submit a list of piles to be installed as part of the indicator pile test program. List shall show type, size, number, location, indicator pile order length, predicted maximum tip elevation, ~~allowable driving stress related to hammer blows, and blow count needed to attain twice the pile design load.~~ If locations for indicator piles differ from those shown on the drawings, provide reasons for change. The proposed revised location will be reviewed and, if appropriate, approved by the Engineer.

2) Submit list prior to ordering indicator piles.

e. Test Documentation and Reports:

~~1) The Contractor shall retain an experienced Engineer employed by a Dynamic Testing Consultant. The Dynamic Testing Consultant's Engineer shall be an integral part of the Contractor's Quality Control Program. Submit the qualifications of the Dynamic Testing Consultant's Registered Maryland Professional Engineer responsible for monitoring Static and Dynamic Pile Testing. The Dynamic Testing Consultant's Engineer shall have a minimum of five (5) years experience in similar work, of which two (2) years shall be field experience with the monitoring of pile driving operations. The Dynamic Testing Consultant shall provide the following:~~

~~a) Results of all Wave Equation Analyses using the GRLWEAP program, Dynamic tests, Static tests and the Case Pile Wave Analysis Program (CAPWAP). The GRLWEAP and CAPWAP program is a product of Globle Rausche Likins and Associates, Inc., 4535 Renaissance Parkway, Cleveland, OH 44128. Telephone (216)831-6131.~~

2) Sample pile driving record/report and sample sketch proposed to show any necessary deviations from planned locations.

3) An annotated sample of the dynamic testing apparatus output. Output shall include recorded input, reduced data and analysis.

4) After completion of each Static and/or Dynamic Pile Test, submit a test report for review and approval by the Engineer. The test report shall include reporting information specified in ASTM D1143 and D4945, results of the refined wave equation analyses, and recommendations for the Production Pile Order List.

5) Prepare a summary report of all the wave equation analyses, CAPWAP, and results of the dynamic and static pile tests. The report shall include test details, hammer and driving system details, soil conditions, instrumentation, test sequence and observations, discussions of test results (including hammer performance, driving stresses, pile integrity and pile capacity), and conclusions and recommendations for the Production Pile Order List.

f. Production Pile Order List:

1) After review and approval of the results of the Static Pile Load Test and Dynamic Pile Testing, submit an "Order List" of production piles proposed to be installed in each pile group. The list shall show type, size, number, location, sequence of installation, length, production maximum tip elevation , allowable driving stress related to hammer blows and blow count needed based on end of initial driving results to attain twice the pile design load for all piles in each pile group.

g. Pile Driving Record:

1) Maintain a record throughout the indicator pile test program and production pile driving operations and submit to the Engineer upon completion of each pile group. The record shall show the applicable established driving criteria developed by the Static Load Test, as modified by Dynamic Testing, for each pile. As a minimum include the following information:

a) Sequence in which piles were driven.

b) Equipment: type, model, serial number.

c) Required blow count per approved driving criteria, allowable driving stress related to hammer blows, production maximum tip elevation and final pile tip elevation.

d) Blow count for each foot of driven length.

e) For all piles, the number of blows per inch of penetration for last 12 inches.

f) Unusual conditions encountered during driving of each pile.

g) Immediately after final pile driving, record top elevation of pile to nearest 0.01 inch. Provide as built pile information after all piles in a pile group have been driven.

1.04 PRODUCT DELIVERY AND HANDLING:

A. Lifting loops shall be used as provided by the precaster. Lifting loops shall not be tied in any way to the pile reinforcement. Loops may remain in place during driving. When handling and delivering precast piles, avoid bending and breaking or chipping of piles.

PART 2 - PRODUCTS

2.01 MATERIALS:

A. Precast concrete piles:
1. Prestressed precast concrete piles in accordance with Sections 03100, 03200, 03300, 03400, and 03415 of these specifications as applicable, shaped as shown.

B. Miscellaneous Driving Accessories: Including driving heads, collars, bands, shoes, and other driving devices in accordance with pile manufacturer's recommendations.

C. Lean concrete: Section 02260.

PART 3 - EXECUTION

3.01 DRIVING EQUIPMENT:

A. The Engineer will review submitted data on driving equipment, accessories and methods for adequacy in conditions expected.

B. Adequacy of equipment and accessories remains the responsibility of the Contractor.

C. Should the equipment used by the Contractor prove inadequate to drive scheduled types of piles at the locations shown, or should progress schedule not be maintained, the Engineer may require replacement of equipment or different expendable accessories or additional equipment.

D. If the hammer, driving block, cushion or any other part of the driving system is changed for any reason, the system must be calibrated by conducting Dynamic Pile Testing to prove the new system is equal to the original system. This work shall be made at no additional time to the Contract and at no cost to the Authority.

3.02 INDICATOR PILE TEST PROGRAM:

A. Installation:
1. No later than twenty-one (21) days prior to driving indicator piles, conduct initial wave equation analysis that represents the subsurface conditions on this project, the pile properties and driving equipment provided. This analysis shall be submitted along with the required pile and driving equipment data to the Engineer.
2. Provide and install indicator piles where shown, to determine lengths of production piles to be furnished to achieve twice the pile design load in the scheduled pile groups. If twice the design load is not attained when the top of the pile is one-foot above planned cut off, discontinue driving for a period of 24 hours or as directed by the Engineer. After the specified period, restrike pile in accordance with Article 3.02.B.1.b. If twice the design load is not attained after restrike, splice the pile, if necessary, and drive it until the specified bearing value is obtained.

3. Locate piles at contract pile locations so they can become part of the completed structure provided they are approved as conforming to requirements specified for production piles. Install indicator piles to achieve pile tips below the predicted maximum tip elevation, in the presence of the Engineer. Assist the Engineer in verifying measurements ~~and driving characteristics~~ as necessary to evaluate the adequacy of the foundation system.
4. The indicator piles scheduled for Static Pile Load Tests are shown on the Contract Drawings. The Engineer may designate alternate or additional indicator piles that exhibit the weakest bearing capacity for Static Pile Load Tests.
5. ~~Piles which are subjected to Static Pile Load Tests which do not pass the acceptance requirements shall be restruck, per 3.02. B.1.b with Dynamic Testing Apparatus installed and functioning, within 48 hours after completion of the Static Pile Load Test to reestablish the minimum required pile length and blow counts.~~
6. Additional piles may be ~~driven,~~ at the Contractor's option, in the area of the Static Load Test Piles to be used as reaction piles. All piles driven as indicator piles or reaction piles for load tests in accordance with the plans and specifications and meeting specified requirements for production piles can, upon approval, be cut off and become a part of the permanent structure.
7. Install all indicator piles that are intended to become part of the permanent structure with the same type and model of equipment and methods to be used to install production piles. Perform work in the presence of the Engineer.
8. Remove piles which are not incorporated into the completed structure or which do
not satisfy test requirements. Alternatively, if rejected piles are not removed then cut off at least three (3) feet below finished grade and backfill resulting hole with lean concrete.

B. Pile Testing:

~~1. Dynamic Pile Testing:~~

~~a. Perform Dynamic Pile Testing in accordance with ASTM D4945.~~

~~b. Install indicator piles where shown with the Dynamic Testing Apparatus installed and functioning to measure performance of the driving system and the bearing capacity. Begin dynamic testing during initial driving when the pile tip achieves the predicted maximum tip elevation. Drive indicator piles to a bearing capacity of at least twice the pile design load based on initial driving. Restrike all indicator piles, with Dynamic Testing Apparatus installed and functioning to verify results from initial driving of these piles. Restrike indicator piles with the hammer at normal operating temperature for a maximum penetration of twelve inches, a maximum of 60 hammer blows, or to less than the driving stress limits established by Article 3.03.B, whichever occurs first. Pile driving shall resume as if it was the initial strike conditions per Article 1.01.A.1.c to obtain the correct pile driving criteria~~

~~c. Perform CAPWAP analyses using the Dynamic Pile Testing data from the end of initial driving and the beginning of restrike of all indicator piles.~~

~~d. Perform refined wave equation analyses using the dynamic test results of each indicator pile. Incorporate the results of the refined wave equation analyses in driving of subsequent indicator piles. Refined wave equation analyses shall be based upon the variations in the~~

~~subsurface conditions and/or drive system performance measured by the dynamic testing apparatus.~~

2. Static Pile Load Tests:
   a. Static Pile Load Test equipment and testing procedures shall be in accordance with ASTM D1143, Quick Load Test Method, except as modified herein.
   b. Provide test equipment with capacity greater than ~~three~~ two times the pile design load and having means of determining applied load to within five (5) percent of test load. Provide test equipment capable of measuring total settlement at the top of the pile to nearest 0.001 inch.
   c. Perform Static Pile Load Tests. Commence loading the pile no sooner than 72 hours after installation of the pile. The maximum test load shall be equal to ~~three~~ two times the pile design load or the ultimate bearing capacity, whichever occurs first.
   ~~d. The ultimate bearing capacity under axial comprehensive load is that load which produces a settlement of the pile head equal to:~~
   ~~$S_u = S + (0.15 + 0.008D)$~~
   ~~Where:~~
   ~~S_u = Settlement at ultimate bearing capacity in inches~~
   ~~S = Elastic deformation of total unsupported pile length in inches~~
   ~~D = Pile diameter or width in inches~~
   e. The safe bearing capacity is defined as 50 percent of the maximum test load. Static load test results will be acceptable when the safe bearing capacity equals or exceeds the design bearing capacity.
   ~~f. Restrike piles for monitoring with Dynamic Testing Apparatus in accordance with Articles 3.02.A.5 and 3.02.B.1.~~

3.03 PRODUCTION PILE DRIVING:

A. Bearing Value, Length and Penetration:
   1. Provide production piles of length necessary to attain production maximum tip elevation, twice the pile design load, and to extend into cap or footing block as shown.
   2. Determine lengths of production piles by analysis of data obtained from Static Pile Load Tests, ~~Dynamic Pile Testing and refined wave equation analyses.~~
   3. Any pile that does not reach twice the pile design load by approved blow count or attain the minimum penetration will be rejected. ~~Rejected piles will be restruck after 48 hours in accordance with Article 3.02.B.1 and ,if necessary tested using Dynamic Pile Testing equipment as directed by the Engineer to prove attained capacity at no additional cost to the Authority.~~
   4. The Contractor may install additional test piles, make borings or make such other investigations as he may desire at no additional time to the Contract and no cost to the Authority.

~~B. Pile Driving Stresses:~~
   ~~1. Indicator and production piles shall not be driven above the hammer energy and blow count shown by the wave equation analyses to produce stresses~~

above the point of impending damage. For concrete piles limit the tensile (TS) and compressive (CS) driving stresses to:

$$TS = 3\sqrt{f'_c} + EPV$$

$$CS = 0.85 f'_c - EP$$

Where:

f'_c = The 28-day design compressive strength of the concrete

EPV = The effective prestress value

2. Cut off grade: At the Contractor's option, production piles reaching design bearing capacity and production maximum tip elevation with tops above the cut off grade may be driven to the cut off grade providing the required bearing capacity is maintained, allowable driving stresses within the pile have not been exceeded and no damage to the pile occurs. Piles damaged or suspected of damage due to driving to achieve a cut off grade shall be pulled and/or replaced at the Contractor's expense.

C. General Requirements:

1. Drive piles only after completion of required excavation or construction of indicated embankments.
2. Stage driving within supported excavation areas so as not to damage internal bracing.
3. For production piles in permanent embankments, pre drill through fill or embankment to natural ground or bottom of embankment.
4. Drive each pile in a continuous operation until required penetration and twice the pile design load have been attained. If driving is stopped before required blow count and penetration have been reached, drive the pile one foot upon resumption of driving before resuming blow count for bearing value determination.
5. Redrive each pile which is lifted 1/4 inch or more by ground heave during driving of adjacent piles to at least the original tip elevation or as directed.
6. Remove loose and displaced material forced up around piles during driving.
7. In Terrace deposits and directly above the Monmouth Formation, cobbles, boulders and cemented sand/silt deposits were found. Penetrate into and through these deposits as necessary to attain twice the pile design load and required maximum tip elevation.
8. Achieve pile penetration through miscellaneous fill, rubble concrete, tires, hardpan, cemented sands/silts, and any other obstruction, natural or man-made, by means of pre-drilling or other approved excavation methods.
9. Hold pile tops in position with steel driving block or anvil.
10. Do not drive piles with free swinging hammer.
11. Pull and replace piles which are not within specified tolerances or, if approved, redesign pile cap as specified. Costs associated with the redesign and construction of modified pile caps will be borne by the Contractor and no additional time to the Contract will be allowed.

D. Pre-drilled Holes.

1. Where shown on the Contract Drawings, drill holes to diameter of greatest cross section dimension of the pile to be installed in accordance with the notes and schedules on the drawings and with Section 2.04.
2. Set pile in pre-drilled hole and drive to predicted or production maximum tip elevation and twice the pile design load, but in all cases to a minimum depth of five (5) feet below bottom of pre-drilled hole.
3. Fill voids between pre-drilled hole and pile with lean concrete immediately upon completion of the driving sequence, as approved.
4. Dispose of material resulting from drilling holes in accordance with the requirements of Section 204.
5. Fill rejected pre-drilled holes with lean concrete and redrill at approved location.

E. Concrete Piles:

1. Cut off piles at such elevation that they will extend into cap or footing as shown. Saw cut piles with equipment capable of providing a flat smooth surface without spalling or damaging pile below cutoff. Replace or repair piles that are damaged when cut off.
2. Where reinforcing steel dowels are shown, dowels may be anchored in cast or drilled holes in concrete pile. If holes are drilled, drill by methods that will not damage concrete, reinforcing steel or prestressing steel. Drill minimum diameter consistent with placing approved epoxy adhesive and dowel. Leave holes free of dust, moisture or other deleterious material. Place sufficient epoxy in holes before inserting dowels leaving no voids afterwards. Leave dowels undisturbed until epoxy has developed 100 percent of its strength capacity.

3.04 FIELD QUALITY CONTROL:

A. Concrete Pile Allowable Tolerances:

1. Ensure straightness and cross-sectional dimensions of precast piles so that a line stretched from butt to tip on any face is not more than one inch from face of pile at any point.
2. Install piles within the following tolerances:
   a. Axis of pile within six inches of design location at cutoff elevation.
   b. Axis of pile not out of plumb or batter by more than one percent of its driven length.
   c. No encroachment of piles upon neat lines of Authority structures.

PART 4 - MEASUREMENT AND PAYMENT

4.01 BASIS:

A. Compensation for work specified in this section will be made in the following manner:

1. Furnishing and installing piles: Linear foot in place in the completed work measured from the tip of the pile to the plane of the cut off (top of pile). This price shall include ~~conducting and reporting the initial wave equation analysis,~~ furnishing piles; ~~driving piles;~~ splices; concreting; achieving specified load and tip elevations.

2. Static Pile Load Test: This work will be measured and paid for at the Contract unit price per each static pile load test performed. The payment will be full compensation for furnishing and setup of test equipment, providing reaction piles, conducting test, reporting and incidentals necessary to complete the work. If load test is terminated by the Engineer because of insufficient bearing capacity, test will be measured for payment. If the test is terminated because of malfunction of Contractor's equipment or other reasons that are the fault of the Contractor, the test will not be measured for payment.

~~3. Dynamic Pile Testing: This work will be measured and paid for at the Contract unit price per dynamic test performed. The payment will be full compensation for furnishing and setup of dynamic testing equipment and conducting test during initial and restrike driving of each indicator pile, performing CAPWAP analyses, performing the refined Wave Equation Analysis, reporting and incidentals necessary to complete the work. Incomplete tests and terminations treated in accordance with Article 4.A.2.~~

~~4. Pile restrike: This work will be measured and paid for at the Contract unit price, per each restrike performed. The payment will be full compensation for furnishing and setup of pile driving equipment required for restriking piles with dynamic equipment installed and functioning in accordance with Article 3.2. If test is terminated by Engineer because of insufficient bearing capacity pile restrike will be measured for payment. If the test is terminated because of malfunction of Contractor's equipment or other reasons that are the fault of the Contractor, pile restrike will not be measured for payment.~~

~~5. Pre-drilled holes shown and specified in Article 3.3 will be paid for at the Contract unit price per linear foot measured from the plane of the cut off (top of pile) to the level of the pre-drilled elevation specified. This price shall include providing the equipment, material and labor necessary to drill holes to the scheduled elevation, disposal of materials, placing lean concrete and incidentals necessary to complete the work.~~

END OF SECTION