PART 1 - GENERAL

1.1 DESCRIPTION

.1 This work shall consist of constructing micropiles as shown on the contract plans and approved working drawings and as specified herein. The micropile specialty Contractor is responsible for furnishing of all design, materials, products, accessories, tools, equipment, services, transportation, labor and supervision, and manufacturing techniques required for design, installation and testing of micropiles and pile top attachments for this project.

.2 The selected micropile Contractor shall select the micropile type, size, pile top attachment, installation means and methods, estimate the ground-grout bond value and determine the required grout bond length and final micropile diameter. The micropile Contractor shall design and install micropiles that will develop the load capacities indicated on the contract plans. The micropile load capacities shall be verified by verification and proof load testing as required and must meet the test acceptance criteria specified herein.

.3 Where the imperative mood is used within this specification, “The Contractor shall” is implied.

1.2 MICROPILE CONTRACTOR’S EXPERIENCE REQUIREMENTS AND SUBMITTALS

.1 The micropile Contractor shall be experienced in the construction and load testing of micropiles and have successfully constructed at least five (5) projects in the last five (5) years involving construction totaling at least 100 micropiles of similar capacity to those required in these plans and specifications.

.2 The Contractor shall have previous micropile drilling and grouting experience in soil/rock similar to project conditions. The Contractor shall submit construction details, structural details and load test results for at least three previous successful micropile load tests from different projects of similar scope to this project.

.3 The Contractor shall assign an Engineer to supervise the work with experience on at least three (3) projects of similar scope to this project completed over the past five (5) years. The Contractor shall not use consultants or manufacturers’ representatives to satisfy the supervising Engineer requirements of this section. The on-site foremen and drill rig operators shall also have experience on at least three (3) projects over the past five (5) years installing micropiles of equal or greater capacity than required in these plans and specifications.

.4 The micropiles shall be designed by a Registered Professional Engineer with experience in the design of at least three (3) successfully completed micropile projects over the past five (5) years, with micropiles of similar capacity to those required in these plans and specifications. The micropile designer may be either an employee of the Contractor or a separate Consultant designer meeting the stated experience requirements.

.5 At least 45 calendar days before the planned start of micropile construction, the Contractor shall submit the completed project reference list and a personnel list. The project reference list shall include a brief project description with the owner’s name and current phone number and load test reports. The personnel list shall identify the micropile system designer (if applicable), supervising project Engineer, drill rig operators, and onsite foremen to be assigned to the project. The personnel list shall contain a summary of each individual’s experience and be complete enough for the Engineer to determine whether each individual satisfies the required qualifications. The Engineer will approve or reject the Contractor’s qualifications within 15 calendar days after receipt of a complete submission. Additional time required due to incomplete or unacceptable submittals will not be cause for time extension or impact or delay claims. All costs associated with incomplete or unacceptable submittals shall be borne by the Contractor.

.6 Work shall not be started, nor materials ordered, until the Engineer's written approval of the Contractor's experience qualifications is given. The Engineer may suspend the Work if the Contractor uses non-approved personnel. If work is suspended, the Contractor shall be fully liable for all resulting costs and no adjustment in contract time will result from the suspension.

1.3 DEFINITIONS

.1 **Admixture**: Substance added to the grout to control bleed and/or shrinkage, improve flowability, reduce water content, or retard setting time.

.2 **Alignment Load (AL)**: An initial load applied to micropile during testing to keep the testing equipment correctly positioned (Typically 5% maximum test load).

.3 **Bonded Length**: The length of the micropile that is bonded to the ground and conceptually used to transfer the applied axial loads to the surrounding soil or rock. Also known as the load transfer length.

.4 **Bond-breaker**: A sleeve placed over the steel reinforcement to prevent load transfer.

.5 **Casing**: Steel tube introduced during the drilling process in overburden soil to temporarily stabilize the drill hole. This is usually withdrawn as the pile is grouted, although in certain types of micropiles, some casing is permanently left in place to provide added pile reinforcement.

.6 **Centralizer**: A device to support and position the reinforcing steel in the drill hole and/or casing so that a minimum grout cover is provided.

.7 **Contractor**: The person/firm responsible for performing the micropile work.

.8 **Coupler**: The means by which load capacity can be transmitted from one partial length of reinforcement to another.

.9 **Creep Movement**: The movement that occurs during the creep test of a micropile under a constant load.

.10 **Design Load (DL)**: The maximum ULS factored load expected to be applied to the micropile during its service life.

.11 **Encapsulation**: A corrugated or deformed tube protecting the reinforcing steel against corrosion.

.12 **Engineer**: The Owner or Owner's authorized agent.

.13 **Free (Unbonded) Length**: The designed length of the micropile that is not bonded to the surrounding ground or grout.

.14 **Geotechnical Bond Design Strength**: For Ultimate Limits States (ULS) or Load Factor Design (LFD), computed as the nominal grout-to-ground bond strength multiplied by a geotechnical resistance factor φ_g. Use:

.1 $\varphi_g = 0.6$ for compression loading

.2 $\varphi_g = 0.4$ for tension loading

.15 **Micropile**: A small-diameter, bored, cast-in-place composite pile, in which the applied load is resisted by steel reinforcement, cement grout and frictional grout/ground bond.

.16 **Maximum Test Load**: The maximum load to which the micropile is subjected during testing

.17 **Nominal Grout-to-Ground Bond Strength**: The estimated ultimate geotechnical unit grout-to-ground bond strength selected for use in design.

.18 **Overburden**: Material, natural or placed, that may require cased drilling methods to provide an open borehole to underlying strata.

.19 **Post-grouting**: The injection of additional grout into the load transfer length of a micropile after the primary grout has set. Also known as regrouting or secondary grouting.

.20 **Primary Grout**: Portland-cement-based grout injected into the micropile hole prior to or after the installation of the reinforcement to direct the load transfer to the surrounding ground along the micropile.

.21 **Proof Load Test**: Incremental loading of a production micropile, recording the total movement at each increment.

.22 **Reinforcement**: The steel component of the micropile that accepts and/or resists applied loadings.

.23 **Sheathing**: Smooth or corrugated piping or tubing that protects the reinforcing steel against corrosion.

.24 **Spacer**: A device to separate elements of a multiple-element reinforcement.

.25 **Ultimate Load (UL)**: Micropile load corresponding to the nominal grout-to-ground bond strength for the pile configuration and dimensions.

.26 **Verification Load Test**: Pile load test performed to verify the design of the pile system and the construction methods proposed, prior to installation of production piles. Test piles are typically constructed to full scale or may be scaled for practical testing purposes.

1.4 REFERENCED CODES AND STANDARDS

.1 The following publications form a part of this specification to the extent indicated by the references. The latest publication as of the issue date of this specification shall govern, unless indicated otherwise:

.2 American Society for Testing and Materials (ASTM) & American Association of State Highway and Transportation Officials (AASHTO)

.1 ASTM A36, A572, AASHTO M183, M223 - Structural Steel

.2 ASTM A1064, AASHTO M55 - Standard Specification for Carbon-Steel Wire and Welded Wire Reinforcement, Plain and Deformed, for Concrete

.3 ASTM A252 - Welded and Seamless Steel Pipe Piles

.4 ASTM A615, AASHTO M31 - Deformed and Plain Billet Steel Bars for Concrete Reinforcement

.5 ASTM A722 - Uncoated High-Strength Steel Bar for Prestressing Concrete

.6 ASTM A775 - Epoxy -Coated Reinforcing Steel Bars

.7 ASTM A934 - Epoxy-Coated Prefabricated Steel Reinforcing Bars

.8 ASTM C33, AASHTO M80 - Concrete Aggregates

.9 ASTM C109 - Compressive Strength of Hydraulic Cement Mortar

.10 ASTM C188, AASHTO T133 - Density of Hydraulic Cement

.11 ASTM C144 - Aggregate for Masonry Mortar

.12 ASTM C150. AASHTO M85 - Portland Cement

.13 ASTM C494, AASHTO M194 - Chemical Admixtures for Concrete

.14 ASTM D1143 - Method of Testing Piles Under Static Axial Compressive Load

.15 ASTM D1784 - Polyvinyl Chloride (PVC) Pipe (Class 13464-B)

.16 ASTM D3350, AASHTO M252 - Polyethylene Corrugated Tubing

.17 ASTM D3689 - Method of Testing Individual Piles Under Static Axial Tensile Load

.18 ASTM D3966 Standard Test Method for Piles Under Lateral Load

.19 AASHTO T26 Quality of Water to be Used in Concrete

.3 Canadian Codes

.1 CSA W59-13 - Welded Steel Construction (Metal Arc Welding)

.2 CSA W186-M1990 (R2012) - Welding of Reinforcing Bars in Reinforced Concrete Construction

.3 CSA G40.20-13/G40.21-13 - General Requirements for Rolled or Welded Structural Quality Steel / Structural Quality Steel.

.4 CSA S16-14 - Design of Steel Structures.

.5 CSA W48-14 - Filler Metals and Allied Materials for Metal Arc Welding.

.6 CSA 47.1-09 (R2014) - Certification of Companies for Fusion Welding of Steel.

.4 American Society of Civil Engineers (ASCE):

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

.5 Deep Foundations Institute (DFI)

.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).

.6 U.S. Department of Transportation, Federal Highway Administration (FHWA)

.1 FHWA-SA-97-070 - Micropile Design and Construction Guidelines Manual

.2 NHI-05-039 - Micropile Design & Construction

1.5 AVAILABLE INFORMATION

.1 Available information developed by the Owner, or by the Owner's duly authorized representative include the following items:

.1 Plans prepared by XXXX, dated XXXX.

.2 Geotechnical Report titled XXXX, dated XXXX.

1.6 CONSTRUCTION SITE SURVEY

.1 Before bidding the Work, the Contractor shall review the available subsurface information and visit the site to assess the site geometry, equipment access conditions, and location of existing structures and above ground facilities.

.2 The Contractor is responsible for field locating and verifying the location of all utilities shown on the plans prior to starting the Work. Maintain uninterrupted service for those utilities designated to remain in service throughout the Work. Notify the Engineer of any utility locations different from shown on the plans that may require micropile relocations or structure design modification. Subject to the Engineer's approval, additional cost to the Contractor due to micropile relocations and/or structure design modification resulting from utility locations different from shown on the plans, will be paid as Extra Work.

.3 Prior to start of any micropile construction activity, the Contractor and Engineer shall jointly inspect the site to observe and document the pre-construction condition of the site, existing structures and facilities.

1.7 MICROPILE DESIGN REQUIREMENTS

.1 The micropiles shall be designed to meet the specified loading conditions, as shown on the contract plans and approved working drawings. Design the micropiles and pile top to footing connections using the Service Load Design (SLD) procedures contained in the FHWA "Micropile Design and Construction Guidelines Manual", Report No. FHWA-SA-97-070.

.2 The required geotechnical resistance factors (for ULS or LFD Design) shall be in accordance with the FHWA manual, unless specified otherwise. Estimated soil/rock design shear strength parameters, unit weights, applied foundation loadings, slope and external surcharge loads, corrosion protection requirements, known utility locations, easements, right-of-ways and other applicable design criteria will be as shown on the plans or specified herein.

.3 Steel pipe used for micropile permanent casing shall incorporate an additional 1.6 mm thickness of sacrificial steel for corrosion protection, unless specified otherwise.

.4 Where required as shown on the contract plans, corrosion protection of the internal steel reinforcing bars, consisting of either encapsulation, epoxy coating, or grout, shall be provided. Where permanent casing is used for a portion of the micropile, encapsulation shall extend at least 1.5 m into the casing.

1.8 MICROPILE DESIGN SUBMITTALS.

.1 At least 21 calendar days before the planned start of micropile structure construction, submit complete design calculations and working drawings to the Engineer for review and approval. Include all details, dimensions, quantities, ground profiles, and cross-sections necessary to construct the micropile structure. Verify the limits of the micropile structure and ground survey data before preparing the detailed working drawings.

.2 The drawings and calculations shall be signed and sealed by the contractor's Professional Engineer or by the Consultant designer's Professional Engineer (if applicable), previously approved by the owner's Engineer. If the micropile contractor uses a consultant design engineer to prepare the design, the micropile contractor shall still have overall contract responsibility for both the design and the construction.

1.9 DESIGN CALCULATIONS

.1 Design calculations shall include, but not be limited to, the following items:

.1 A written summary report which describes the overall micropile design.

.2 Applicable code requirements and design references.

.3 Design calculation sheets (both static and seismic) with the project number, micropile structure location, designation, date of preparation, initials of designer and checker, and page number at the top of each page.

.4 Micropile structure critical design cross-section(s) geometry including soil/rock strata and water levels and location, magnitude and direction of design applied loadings, including slope or external surcharge loads.

.5 Design criteria including, soil/rock shear strengths (friction angle and cohesion), unit weights, and ground-grout bond values and micropile drill-hole diameter assumptions for each soil/rock strata.

.6 Load and resistance factors used in the design on the ground-grout bond values, surcharges, soil/rock and material unit weights, steel, grout, and concrete materials.

.7 Seismic design earthquake acceleration coefficient.

.8 Design notes including an explanation of any symbols and computer programs used in the design.

.9 Pile to footing connection calculations.

1.10 WORKING DRAWINGS

.1 The working drawings shall include all information required for the construction and quality control of the piling. Working drawings shall include, but not be limited to, the following items unless provided in the contract plans:

.1 A plan view of the micropile structure(s) identifying:

.1 A reference baseline and elevation datum.

.2 The offset from the construction centerline or baseline to the face of the micropile structure at all changes in horizontal alignment.

.3 Beginning and end of micropile structure stations.

.4 Right-of-way and permanent or temporary construction easement limits, location of all known active and abandoned existing utilities, adjacent structures or other potential interferences. The centerline of any drainage structure or drainage pipe behind, passing through, or passing under the micropile structure.

.5 Subsurface exploration locations shown on a plan view of the proposed micropile structure alignment with appropriate reference base lines to fix the locations of the explorations relative to the micropile structure.

.2 An elevation view of the micropile structure(s) identifying:

.1 Elevation view showing micropile locations and elevations; vertical and horizontal spacing; batter and alignment and the location of drainage elements (if applicable).

.2 Existing and finish grade profiles both behind and in front of the micropile structure.

.3 Design parameters and applicable codes.

.4 General notes for constructing the micropile structure including construction sequencing or other special construction requirements.

.5 Horizontal and vertical curve data affecting the micropile structure and micropile structure control points. Match lines or other details to relate micropile structure stationing to centerline stationing.

.6 A listing of the summary of quantities on the elevation drawing of each micropile structure showing pay item estimated quantities (if applicable).

.7 Micropile typical sections including micropile spacing and inclination; minimum drillhole diameter; pipe casing and reinforcing bar sizes and details; splice types and locations; centralizers and spacers; grout bond zone and casing plunge lengths (if used); corrosion protection details; and connection details to the substructure footing, anchorage, plates, etc.

.8 A typical detail of verification and production proof test micropiles defining the micropile length, minimum drillhole diameter, inclination, and load test bonded and unbonded test lengths (if applicable).

.9 Details, dimensions, and schedules for all micropiles, casing and reinforcing steel, including reinforcing bar bending details.

.10 Revise the drawings when plan dimensions are changed due to field conditions or for other reasons. Within 30 days after completion of the work, submit as-built drawings to the Engineer. Provide revised design calculations signed by the approved Registered Professional Engineer for all design changes made during the construction of the micropile structure.

1.11 CONSTRUCTION SUBMITTALS

.1 Work other than test pile installation shall not begin until the construction submittals have been received, reviewed, and accepted in writing by the Engineer. Provide work plan, schedule, welding procedure, headroom requirements and surface water control plan at least 21 calendar days prior to initiating micropile construction.

.2 Provide mill reports as the work progresses for each delivery.

.3 Provide grout plan and load test plan at least seven days prior to start of micropile load testing or incorporation of the respective materials into the work.

.4 The Contractor shall allow the Engineer seven (7) calendar days to review the construction submittals after a complete set has been received. Additional time required due to incomplete or unacceptable submittals shall not be cause for delay or impact claims. All costs associated with incomplete or unacceptable Contractor submittals shall be the responsibility of the Contractor.

.5 Work Plan: Detailed step-by-step description of the proposed micropile construction procedure, including personnel, testing and equipment to assure quality control. This step-by-step procedure shall be shown on the working drawings in sufficient detail to allow the Engineer to monitor the construction and quality of the micropiles.

.6 Schedule: Proposed start date and time schedule and micropile installation schedule providing the following:

.1 Micropile number

.2 Micropile design load

.3 Type and size of reinforcing steel

.4 Minimum total bond length

.5 Total micropile length

.6 Micropile top footing attachment

.7 Welding procedure: If welding of casing is proposed, submit the proposed welding procedure, certified by a qualified welding specialist.

.8 Information on headroom and space requirements for installation equipment that verify the proposed equipment can perform at the site.

.9 Surface Water Control Plan describing how surface water, drill flush, and excess waste grout will be controlled and disposed.

.10 Certified mill test reports for the reinforcing steel or coupon test results for permanent casing without mill certification. The ultimate strength, yield strength, elongation, and material properties composition shall be included. For API N-80 pipe casing, coupon test results may be submitted in lieu of mill certification.

.11 Proposed Grouting Plan. The grouting plan shall include complete descriptions, details, and supporting calculations for the following:

.1 Grout mix design and type of materials to be used in the grout including certified test data and trial batch reports.

.2 Methods and equipment for accurately monitoring and recording the grout depth, grout volume and grout pressure as the grout is being placed.

.3 Grouting rate calculations, when requested by the Engineer. The calculations shall be based on the initial pump pressures or static head on the grout and losses throughout the placing system, including anticipated head of drilling fluid (if applicable) to be displaced.

.4 Estimated curing time for grout to achieve specified strength. Previous test results for the proposed grout mix completed within one year of the start of grouting may be submitted for initial verification and acceptance and start of production work. During production, grout shall be tested in accord with PART 3.

.5 Procedure and equipment for Contractor monitoring of grout quality.

.12 Load Testing Plan: Detailed plans for the proposed micropile load testing method. This shall include all drawings, details, and structural design calculations necessary to clearly describe the proposed test method, reaction load system capacity and equipment setup, types and accuracy of apparatus to be used for applying and measuring the test loads and pile top movements in accordance with Section 3.12, Pile Load Tests.

.13 Calibration reports and data for each test jack, pressure gauge and master pressure gauge and electronic load cell to be used. The calibration tests shall have been performed by an independent testing laboratory, and tests shall have been performed within 90 calendar days of the date submitted. Testing shall not commence until the Engineer has reviewed and accepted the jack, pressure gauge, master pressure gauge and electronic load cell calibration data.

1.12 PRE-CONSTRUCTION MEETING

.1 A pre-construction meeting will be scheduled by the Contractor and held prior to the start of micropile construction. The Engineer, prime Contractor, micropile specialty Contractor, micropile designer, excavation Contractor and geotechnical instrumentation specialist (if applicable) shall attend the meeting. Attendance is mandatory. The pre-construction meeting will be conducted to clarify the construction requirements for the work, to coordinate the construction schedule and activities, and to identify contractual relationships and delineation of responsibilities amongst the prime Contractor and the various Subcontractors – specifically those pertaining to excavation for micropile structures, anticipated subsurface conditions, micropile installation and testing, micropile structure survey control and site drainage control.

1.13 PAYMENT

.1 All costs for items specified in this section are to be included in the Lump Sum Tender Price, including all testing.

PART 2 - MATERIALS

.1 Furnish materials new and without defects. Remove defective materials from the jobsite at no additional cost. Materials for micropiles shall consist of the following:

.1 **Admixtures for Grout**: Admixtures shall conform to the requirements of ASTM C494/AASHTO M194. Admixtures that control bleed, improve flowability, reduce water content, and retard set may be used in the grout, subject to the review and acceptance of the Engineer. Admixtures shall be compatible with the grout and mixed in accordance with the manufacturer's recommendations. Expansive admixtures shall only be added to the grout used for filling sealed encapsulations and anchorage covers. Accelerators are not permitted. Admixtures containing chlorides are not permitted.

.2 **Cement**: All cement shall be Portland cement conforming to ASTM C lSO/AASHTO M85, Types II, III or V.

.3 **Centralizers and Spacers**: Centralizers and spacers shall be fabricated from schedule 40 PVC pipe or tube, steel, or material non-detrimental to the reinforcing steel. Wood shall not be used. Centralizers and spacers shall be securely attached to the reinforcement; sized to position the reinforcement within 10 mm of plan location from center of pile; sized to allow grout tremie pipe insertion to the bottom of the drillhole; and sized to allow grout to freely flow up the drillhole and casing and between adjacent reinforcing bars.

.4 **Encapsulation**: Encapsulation (double corrosion protection) shall be shop fabricated using high-density, corrugated polyethylene tubing conforming to the requirements of ASTM D3350/AASHTO M252 with a nominal wall thickness of 0.8 mm. The inside annulus between the reinforcing bars and the encapsulating tube shall be a minimum of 5mm and be fully grouted with non-shrink grout conforming to PART 2.

.5 **Epoxy Coating**: The minimum thickness of coating applied electrostatically to the reinforcing steel shall be 0.3 mm. Epoxy coating shall be in accordance with ASTM A775 or ASTM A934. Bend test requirements are waived. Bearing plates and nuts encased in the pile concrete footing need not be epoxy coated.

.6 **Fine Aggregate**: If sand - cement grout is used, sand shall conform to ASTM C 144/AASHTO M45.

.7 **Grout**: Neat cement or sand/cement mixture with a minimum three (3)-day compressive strength of 14 MPa and a 28day compressive strength of 28 MPa per AASHTO T106/ASTM C109.

.8 **Grout Protection**: Provide a minimum 25 mm grout cover over bare or epoxy coated bars (excluding bar couplers) or minimum 12 mm grout cover over the encapsulation of encapsulated bars.

.9 **Permanent Casing Pipe**: Permanent steel casing/pipe shall have the diameter and at least minimum wall thickness shown on the approved Working Drawings. The permanent steel casing/pipe:

.1 Shall meet the Tensile Requirements of ASTM A252, Grade 3, except the yield strength shall be a minimum of 345 MPa to 552 MPa as used in the design submittal.

.2 .2 May be new “Structural Grade” (a.k.a. “Mill Secondary”) steel pipe meeting above but without Mill Certification, free from defects (dents, cracks, tears) and with two (2) coupon tests per truckload delivered to the fabricator.

.10 For permanent casing/pipe that will be welded, the following material conditions apply:

.1 The carbon equivalency (CE) as defined in AWS D1.1, Section X15.1, shall not exceed 0.45, as demonstrated by mill certifications

.2 The sulfur content shall not exceed 0.05%, as demonstrated by mill certifications

.11 For permanent casing/pipe that will be shop or field welded, the following fabrication or construction conditions apply:

.1 The steel pipe shall not be joined by welded lap splicing

.2 Welded seams and splices shall be complete penetration welds

.3 Partial penetration welds may be restored in conformance with AWS D1.1

.4 The proposed welding procedure certified by a welding specialist shall be submitted for approval

.12 Threaded casing joints shall develop at least the required nominal resistance used in the design of the micropile.

.13 **Plates and Shapes**: Structural steel plates and shapes for pile top attachments shall conform to CSA G40.21 Grade 350.

.14 Reinforcing Bars: Reinforcing steel shall be deformed bars in accordance with ASTM A615/AASHTO M31, Grade 420 or Grade 520 or ASTM A722/AASHTO M275, Grade 1035. When a bearing plate and nut are required to be threaded onto the top end of reinforcing bars for the pile top to footing anchorage, the threading may be continuous spiral deformed ribbing provided by the bar deformations (e.g., Dywidag or Williams continuous threadbars) or may be cut into a reinforcing bar. If threads are cut into a reinforcing bar, the next larger bar number designation from that shown on the Plans shall be provided, at no additional cost. All bars to be double corrosion protected.

.15 Bar tendon couplers, if required, shall develop the ultimate tensile strength of the bars without evidence of any failure.

.16 Sheathing: Smooth or corrugated plastic sheathing, including joints, shall be watertight. Polyvinyl chloride (PVC) sheathing shall conform to ASTM D1784, Class 13464-B.

.17 Water: Water used in the grout mix shall conform to AASHTO T26 and shall be potable, clean, and free from substances that may be injurious to cement and steel.

PART 3 - EXECUTION

.1 Site drainage control.

.1 The Contractor shall control and properly dispose of drill flush and construction related waste, including excess grout, in accord with the standard specifications and all applicable local codes and regulations. Provide positive control and discharge of all surface water that will affect construction of the micropile installation. Maintain all pipes or conduits used to control surface water during construction. Repair damage caused by surface water at no additional cost. Upon substantial completion of the Work, remove surface water control pipes or conduits from the site. Alternatively, with the approval of the Engineer, pipes or conduits that are left in place may be fully grouted and abandoned or left in a way that protects the structure and all adjacent facilities from migration of fines through the pipe or conduit and potential ground loss.

.2 Excavation

.1 Coordinate the work and the excavation so the micropile structures are safely constructed. Perform the micropile construction and related excavation in accordance with the Plans and approved submittals. No excavations steeper than those specified herein or shown on the Plans will be made above or below the micropile structure locations without written approval of the Engineer.

.2 Immediately contact the Engineer if unanticipated existing subsurface structures are discovered during excavation or drilling. Suspend work in these areas until remedial measures meeting the Engineer's approval are implemented.

.3 Micropile Allowable Construction Tolerances

.1 Centerline of piling shall not be more than 75 mm from indicated plan location.

.2 Pile shall be plumb within 2% of total-length plan alignment.

.3 Top elevation of pile shall be plus 25 mm or minus 50 mm maximum from vertical elevation indicated.

.4 Centerline of reinforcing steel shall not be more than 15 mm from indicated location.

.4 Micropile Installation

.1 The micropile Contractor shall select the drilling method, the grouting procedure and the grouting pressure used for the installation of the micropiles. The micropile Contractor shall also determine the micropile casing size, final drillhole diameter and bond length, and central tendon reinforcement steel sizing necessary to develop the specified load capacities and load testing requirements. The micropile Contractor is also responsible for estimating the grout take. There will be no extra payment for grout overruns.

.2 Drilling

.1 The drilling equipment and methods shall be suitable for drilling through the conditions to be encountered, without causing damage to any overlying or adjacent structures or services. The drillhole must be open along its full length to

at least the design minimum drillhole diameter prior to placing grout and reinforcement.

.2 Temporary casing or other approved method of anchor drillhole support will be required in caving or unstable ground to permit the anchor shaft to be formed to the minimum design drillhole diameter. The Contractor's proposed method(s) to provide drillhole support and to prevent detrimental ground movements shall be reviewed by the Engineer. Detrimental ground movement is defined as movement which requires remedial repair measures. Use of drilling fluid containing bentonite is not allowed.

.3 Ground Heave or Subsidence

.1 During construction, the Contractor shall observe the conditions vicinity of the micropile construction site on a daily basis for signs of ground heave or subsidence. Immediately notify the Engineer if signs of movements are observed. Contractor shall immediately suspend or modify drilling or grouting operations if ground heave or subsidence is observed, if the micropile structure is adversely affected, or if adjacent structures are damaged from the drilling or grouting. If the Engineer determines that the movements require corrective action, the Contractor shall take corrective actions necessary to stop the movement or perform repairs. When due to the Contractor's methods or operations or failure to follow the specified/approved construction sequence, as determined by the Engineer, the costs of providing corrective actions will be borne by the Contractor. When due to differing site conditions, as determined by the Engineer, the costs of providing corrective actions will be paid as Extra Work.

.4 Pipe Casing and Reinforcing Bars Placement and Splicing

.1 Reinforcement may be placed either prior to grouting or placed into the grout - filled drillhole before temporary casing (if used) is withdrawn. Reinforcement surface shall be free of deleterious substances such as soil, mud, grease or oil that might contaminate the grout or coat the reinforcement and impair bond. Pile cages and reinforcement groups, if used, shall be sufficiently robust to withstand the installation and grouting process and the withdrawal of the drill casings without damage or disturbance.

.2 The Contractor shall check pile top elevations and adjust all installed micropiles to the planned elevations.

.3 Centralizers and spacers (if used) shall be provided at 3 m centers maximum spacing. The upper and lower most centralizer shall be located a maximum of 1.5 m from the top and bottom of the micropile. Centralizers and spacers shall permit the free flow of grout without misalignment of the reinforcing bar(s) and permanent casing. The central reinforcement bars with centralizers shall be lowered into the stabilized drillhole and set. The reinforcing steel shall be inserted into the drill hole to the desired depth without difficulty. Partially inserted reinforcing bars shall not be driven or forced into the hole. Contractor shall redrill and reinsert reinforcing steel when necessary to facilitate insertion.

.4 Lengths of casing and reinforcing bars to be spliced shall be secured in proper alignment and in a manner to avoid eccentricity or angle between the axes of the two lengths to be spliced. Splices and threaded joints shall meet the requirements of PART 2. Threaded pipe casing joints shall be located at least two casing diameters (OD) from a splice in any reinforcing bar. When multiple bars are used, bar splices shall be staggered at least 0.3 meters.

.5 Grouting

.1 Micropiles shall be primary grouted the same day the load transfer bond length is drilled. The Contractor shall use a stable neat cement grout or a sand cement grout with a minimum 28-day unconfined compressive strength of 28 MPa. Admixtures, if used, shall be mixed in accordance with manufacturer's recommendations. The grouting equipment used shall produce a grout free of lumps and undispersed cement. The Contractor shall have means and methods of measuring the grout quantity and pumping pressure during the grouting operations. The grout pump shall be equipped with a pressure gauge to monitor grout pressures. A second pressure gauge shall be placed at the point of injection into the pile top. The pressure gauges shall be capable of measuring pressures of at least 1 MPa or twice the actual grout pressures used, whichever is greater. The grout shall be kept in agitation prior to mixing. Grout shall be placed within one hour of mixing. The grouting equipment shall be sized to enable each pile to be grouted in one continuous operation. The grout shall be injected from the lowest point of the drill hole and injection shall continue until uncontaminated grout flows from the top of the pile. The grout may be pumped through grout tubes, casing, hollow-stem augers, or drill rods. Temporary casing, if used, shall be extracted in stages ensuring that, after each length of casing is removed the grout level is brought back up to the ground level before the next length is removed. The tremie pipe or casing shall always extend below the level of the existing grout in the drillhole. The grout pressures and grout takes shall be controlled to prevent excessive heave or fracturing of rock or soil formations. Upon completion of grouting, the grout tube may remain in the hole, but must be filled with grout.

.2 The grout shall be injected from the lowest point of the drill hole and injection shall continue until uncontaminated grout flows from the top of the pile. The grout may be pumped through grout tubes, casing, hollow-stem augers, or drill rods. Temporary casing, if used, shall be extracted in stages ensuring that, after each length of casing is removed the grout level is brought back up to the ground level before the next length is removed. The tremie pipe or casing shall always extend below the level of the existing grout in the drillhole. The grout pressures and grout takes shall be controlled to prevent excessive heave or fracturing of rock or soil formations. Upon completion of grouting, the grout tube may remain in the hole, but must be filled with grout.

.3 Grout within the micropiles shall be allowed to attain the required design strength prior to being loaded.

.4 If the Contractor elects to use a postgrouting system, Working Drawings and details shall be submitted to the Engineer for review.

.6 Grout Testing

.1 Grout within the micropile verification and proof test piles shall attain the minimum required three (3)-day compressive strength of 14 MPa prior to load testing. Previous test results for the proposed grout mix completed within one year of the start of work may be submitted for initial verification of the required compressive strengths for installation of pre-production verification test piles and initial production piles. During production, micropile grout shall be tested by the Contractor for compressive strength in accordance with AASHTO T106/ASTM C109 at a frequency of no less than one set of three 50-mm grout cubes from each grout plant each day of operation or per every 10 piles, whichever occurs more frequently. The compressive strength shall be the average of the 3 cubes tested.

.2 Grout consistency as measured by grout density shall be determined by the Contractor per ASTM C188/AASHTO T133 or API RP-13B-1 at a frequency of at least one test per pile, conducted just prior to start of pile grouting. The Baroid Mud Balance used in accordance with API RP-13B-1 is an approved device for determining the grout density of neat cement grout. The measured grout density shall be as indicated on working drawings provided by the Contractor.

.3 Grout samples shall be taken directly from the grout plant. Provide grout cube compressive strength and grout density test results to the Engineer within 24 hours of testing.

.7 Micropile Installation Records

.1 Contractor shall prepare and submit to the Engineer full-length installation records for each micropile installed. The records shall be submitted within one work shift after that pile installation is completed. The data shall be recorded on the micropile installation log included at the end of this specification. A separate log shall be provided for each micropile.

.5 Pile Load Tests

.1 Perform verification and proof testing of piles at the locations specified herein or designated by the Engineer. Perform compression load testing in accord with ASTM D1143 and tension load testing in accord with ASTM D3689, except as modified herein.

.2 The maximum verification and proof test loads applied to the micropile shall not exceed 80% of the structural capacity of the micropile structural elements, to include steel yield in tension, steel yield or buckling in compression, or grout crushing in compression. Any required increase in strength of the verification test pile elements above the strength required for the production piles shall be provided for in the contractor’s bid price.

.3 The jack shall be positioned at the beginning of the test such that unloading and repositioning during the test will not be required. When both compression and tension load testing is to be performed on the same pile, the pile shall be tested under compression loads prior to testing under tension loads.

.4 For convenience of testing and set-up, pile testing may be performed in tension, regardless of the governing load, with reference to the maximum governing load, unless specified otherwise.

.5 Testing Equipment and Data Recording

.1 Testing equipment shall include dial gauges, dial gauge support, jack and pressure gauge, electronic load cell, and a reaction frame. The load cell is required only for the creep test portion of the verification test. The contractor shall provide a description of test setup and jack, pressure gauge and load cell calibration curves in accordance with the Submittals Section.

.2 Design the testing reaction frame to be sufficiently rigid and of adequate dimensions such that excessive deformation of the testing equipment does not occur. Align the jack, bearing plates, and stressing anchorage such that unloading and repositioning of the equipment will not be required during the test.

.3 Apply and measure the test load with a hydraulic jack and pressure gauge. The pressure gauge shall be graduated in 500kPa increments or less. The jack and pressure gauge shall have a pressure range not exceeding twice the anticipated maximum test pressure. Jack ram travel shall be sufficient to allow the test to be done without resetting the equipment. Monitor the creep test load hold during

verification tests with both the pressure gauge and the electronic load cell. Use the load cell to accurately maintain a constant load hold during the creep test load hold increment of the verification test.

.4 Measure the pile top movement with a dial gauge capable of measuring to 0.025 mm. The dial gauge shall have a travel sufficient to allow the test to be done without having to reset the gauge. Visually align the gauge to be parallel with the axis of the micropile and support the gauge independently from the jack, pile or reaction frame. Use a minimum of two dial gauges when the test setup requires reaction against the ground or single reaction piles on each side of the test pile.

.5 The required load test data shall be recorded by the Engineer.

.6 Verification Load Tests

.1 Perform pre-production verification pile load testing to verify the design of the pile system and the construction methods proposed prior to installing any production piles.

.2 Verification load tests shall be performed to verify that the Contractor installed micropiles will meet the required tension load capacities and load test acceptance criteria and to verify that the length of the micropile load transfer bond zone is adequate. The micropile verification load test results must verify the Contractor's design and installation methods, and be reviewed and accepted by the Engineer prior to beginning installation of production micropiles. Installation of production piles should not proceed until all verification test results have been reviewed and accepted by the Engineer.

.3 Piles used for pre-production testing should not remain in place for usage as production piles unless reviewed and accepted by the engineer. Test piles to be removed or cut-off and abandoned following completion of testing.

.4 Verification Test Pile Configuration and Construction

.1 The drilling-and-grouting method, casing size, and drill size for the verification test pile(s) shall be identical to those specified for the production piles at the given locations. The verification test micropile structural steel sections shall be sized to safely resist the maximum test load.

.2 Test verification piles can be full-scale (same configuration and dimensions as production piles) or they may be scaled to allowable practical limitations of testing equipment and materials.

.3 Where verification test piles are scaled:

.1 Effective bond length shall be no less than 50% of the production pile bond and a minimum of 1.5m.

.2 Maximum test load for verification testing shall be scaled to test for the corresponding nominal grout-to-ground bond strength

.5 Verification Test Quantities and Location

.1 Two (2) sacrificial verification test piles shall be constructed in conformance with the approved Working Drawings.

.2 Verification test pile(s) shall be installed at the locations proposed by the Contractor and approved by the Engineer. Test piles are to be located such that their installation and performance is representative of production piles, and in locations that will not interfere with production pile installation.

.6 Verification Test Loading Schedule

.1 Test verification piles to a maximum test load corresponding to the nominal grout-to-ground bond strength based on the test pile configuration (full-scale or scaled) or Ultimate Load (UL).

.2 The verification pile load tests shall be made by incrementally loading the micropile in accordance with the load schedule for the governing load(s):

LOAD	HOLD TIME
AL	1 min
0.10UL	1 min
0.15UL	1 min
0.20UL	1 min
0.25UL	1 min
0.30UL	1 min
0.35UL	1 min
0.40UL	1 min
0.45UL	1 min
0.50UL	1 min
0.55UL	1 min
0.60UL	1 min
0.65UL	1 min
0.70UL	1 min
0.75UL	1 min
0.80UL	1 min
0.85UL	1 min
0.90UL	1 min
0.95UL	1 min
1.00UL	CREEP TEST (10min to 60min)
0.80UL	1 min
0.60UL	1 min
0.40UL	1 min
0.20UL	1 min
AL	1min

.3 The alignment load (AL) shall not exceed 5% of the UL. Dial gauges shall be reset to zero after the initial AL is applied.

.4 The test load shall be applied in increments of 10 percent of the UL. Each load increment shall be held for a minimum of 1 minute. Pile top movement shall be measured at each load increment. The load-hold

period shall start as soon as each test load increment is applied. Unloading shall be applied in decrements of 20% of the UL.

.5 The verification test pile shall be monitored for creep at the maximum test load (1.00UL): hold the pile load for 10min and record displacement at 0, 1, 2, 3, 4, 6, 10 minutes. If net creep from 1 to 10 minutes exceeds 1.0mm, hold for additional 50min with displacement readings at 20, 30, 50, and 60 minutes

.7 The acceptance criteria for micropile verification load tests are:

.1 At the end of the creep test at the maximum test load, test piles shall have a creep rate not exceeding 2.0mm/log cycle time. The creep rate shall be linear or decreasing throughout the creep load hold period.

.2 Failure does not occur at the maximum test load. Failure is defined as load at which attempts to further increase the test load simply result in continued pile movement.

.3 The Engineer will provide the Contractor written confirmation of the micropile design and construction within three (3) working days of the completion of the verification load tests. This written confirmation will either confirm the capacities and bond lengths specified in the Working Drawings for micropiles or reject the piles based upon the verification test results.

.8 Verification Test Pile Rejection

.1 If a verification tested micropile fails to meet the acceptance criteria, the Contractor shall modify the design, the construction procedure, or both. These modifications may include modifying the installation methods, increasing the bond length, or changing the micropile type. Any modification that necessitates changes to the structure shall require the Engineer's prior review and acceptance. Any modifications of design or construction procedures or cost of additional verification test piles and load testing shall be at the Contractor's expense. At the completion of verification testing, test piles shall be removed down to the elevation specified by the Engineer.

.7 Proof Load Tests *(MAY NOT BE REQUIRED DEPENDING ON PROJECT)*

.1 Proof Test Quantities and Locations

.1 Perform proof load tests on the first two (2) production piles installed, prior to the installation of the remaining production piles.

.2 Proof testing shall be conducted at a frequency of 5% (1 in 20) of the subsequent production piles installed beyond the first 20. Location of additional proof test piles shall be as designated by the Engineer.

.2 Proof Test Loading Schedule

.1 Test piles designated for tension proof load testing to a maximum test load of 100% of the factored micropile Design Load (DL) shown on the Plans or Working Drawings.

.2 Proof tests shall be made by incrementally loading the micropile in accordance with the following schedule:

LOAD	HOLD TIME
AL	1 min
0.20DL	1 min
0.40DL	1 min
0.60DL	1 min
0.80DL	1 min
1.00DL	CREEP TEST (10min to 60min)
AL	1min

.3 The alignment load (AL) shall not exceed 5% of the DL. Dial gauges shall be reset to zero after the initial AL is applied.

.4 The test load shall be applied in increments of 20 percent of the DL. Each load increment shall be held for a minimum of 1 minute. Pile top movement shall be measured at each load increment. The load-hold period shall start as soon as each test load increment is applied. Unloading shall be applied in one decrement to the AL.

.5 The verification test pile shall be monitored for creep at the maximum test load (1.00DL): hold the pile load for 10min and record displacement at 0, 1, 2, 3, 4, 6, 10 minutes. If net creep from 1 to 10 minutes exceeds 1.0mm, hold for additional 50min with displacement readings at 20, 30, 50, and 60 minutes

.3 The acceptance criteria for micropile proof load tests are:

.1 At the end of the 1.00DL creep test load increment, test piles shall have a creep rate not exceeding 1 mm/log cycle time. The creep rate shall be linear or decreasing throughout the creep load hold period.

.2 Failure does not occur at the 1.00DL maximum test load. Failure is defined as the load at which attempts to further increase the test load simply result in continued pile movement.

.4 Proof Test Pile Rejection

.1 If a proof-tested micropile fails to meet the acceptance criteria, the Contractor shall immediately proof test another micropile within that footing. For failed piles and further construction of other piles, the Contractor shall modify the design, the construction procedure, or both. These modifications may include installing replacement micropiles, incorporating piles at not more than 50% of the maximum load attained, postgrouting, modifying installation methods, increasing the bond length, or changing the micropile type. Any modification that necessitates changes to the structure design shall require the Engineer's prior review and acceptance. Any modifications of design or construction procedures, or cost of additional verification test piles and verification and/or proof load testing, or replacement production micropiles, shall be at the Contractor's expense.

END OF SECTION – 02345