

## MICROPILE FOUNDATIONS

### **Description**

This work shall consist of constructing micropiles in accordance with 105.03 and the 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.

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 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 shall meet the test acceptance criteria specified herein.

Production pile installation, except reaction piles and load test piles, shall not begin prior to conducting the load tests.

The Engineer will monitor and record the installation of all micropiles and will record the load test data and interpret the results of the load tests.

### **Qualifications of Micropile Contractor**

The qualified micropile contractor shall have installed micropile foundations with dimensions and capacity similar to those shown on the plans for a minimum of five projects in the last five years, involving construction totaling at least 100 micropiles prior to the bid date for this project.

The micropile contractor shall have previous micropile drilling and grouting experience in soil and rock similar to this project conditions. The micropile 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.

The on-site foremen and drill rig operators shall also have experience on at least three projects over the past five years installing micropiles of equal or greater capacity than required in these plans and specifications. The Contractor shall not use consultants or manufacturers' representatives to satisfy the supervising Engineer requirements of this section. The micropile contractor shall also provide resumes of key personnel who will be present on site and who will each have at least three years of relevant experience.

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

### **Definitions**

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

*Alignment Load (AL):* A minimum initial load (no greater than 10% of the Design Load) applied to micropile during testing to keep the test equipment correctly positioned.

*Bond Length:* The length of the micropile that is bonded to the ground and used to transfer the applied axial loads to the surrounding soil or rock.

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

*Casing:* Steel tube introduced during the drilling process in overburden soil to temporarily stabilize the drillhole. 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.

*Centralizer:* A device to support and position the reinforcing steel in the drillhole and casing so that a minimum grout cover is provided.

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

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

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

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

*Excess Grout:* This is the grout that overflows out of the micropile hole and needs to be cleaned up and disposed of properly.

*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.

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

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

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

*Plunging Load (PL):* The load corresponding to a settlement equal to 20% of the pile diameter or a load at which settlement stabilization is not obtained even with reduction in the load increment specified herein.

*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.

*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.

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

*Reinforcement:* The reinforcing steel bar component of the micropile that accept and resist applied loading.

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

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

*Structural Load (SL):* The factored structural capacity of the micropile.

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

*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.

#### **Available Information**

Available information includes the following items:

1. Contract Plans: Plans prepared by Beam, Longest and Neff, LLC, dated August 2, 2016.
2. Geotechnical Report INDOT Project No. 1006343, Des. No. 1006343 and 1006345, dated January 7, 2016, included in the bid documents, contains the results of test borings and other site investigation data obtained in the vicinity of the proposed micropile locations.

#### **Construction Site Survey**

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.

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.

#### **Micropile Design Requirements**

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 procedures contained in the FHWA "Micropile Design and Construction", Report No. FHWA NHI-05-039.

The geotechnical and structural capacity of the micropiles shall be determined in accordance with the AASHTO LRFD Bridge Specifications, Seventh

Edition. Estimated soil/rock design shear strength parameters, applied foundation loadings, corrosion protection requirements and other applicable design criteria will be as shown on the plans or specified herein.

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 5 feet into the casing.

### **Submittals and Meetings**

#### **(a) Personnel Submittal**

At least 45 calendar days before the planned start of micropile construction, the Contractor shall submit copies of the completed project reference list and a personnel list. The project reference list shall include a brief project description with the Department's name and current phone number and load test reports. The personnel list shall identify the micropile system design engineer, project supervisor, drill rig operators, and on-site 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 receipts of a complete submission.

#### **(b) Micropile Working Drawing Submittal**

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.

The drawings and calculations shall be signed and sealed by a Professional Engineer registered in the State of Indiana in accordance with 105.02. 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) Design Calculations.**

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

- a. A written summary report which describes the overall micropile design.
- b. Applicable code requirements and design references.
- c. Micropile structure critical design cross-section(s) geometry including soil/rock strata and piezometric levels and location, magnitude and direction of design applied loadings, including slope or external surcharge loads.
- d. Design criteria including, soil/rock shear strengths (friction angle and cohesion), unit weights, and ground-grout bond values and micropile drillhole diameter assumptions for each soil/rock strata.
- e. Seismic design earthquake acceleration coefficient.
- f. Design calculation sheets, both static and seismic(if required) 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. Provide an index page with the design calculations.
- g. Design notes including an explanation of any symbols and computer programs used in the design.
  - h. Pile to footing connection calculations.

**(2) Working Drawings.**

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:

- a. A plan view of the pile cap and micropiles identifying:
  - 1. A reference baseline and elevation datum.
  - 2. The offset from the centerline of pile cap to the centerline of micropile
  - 3. Subsurface exploration locations.
- b. An elevation view of the pile cap and micropiles 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 pile cap.
- c. Design parameters and applicable codes.
- d. General notes for constructing the micropile structure including construction sequencing or other special construction requirements.
- e. A listing of the summary of quantities on the elevation drawing of each pile cap showing estimated quantities.
- f. Micropile typical sections including micropile spacing and inclination (if required); 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.
- g. 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.
- h. Details, dimensions, and bill of materials for all micropiles, casing and reinforcing steel, including reinforcing bar bending details.
- i. Details for constructing micropile structures around drainage facilities (if applicable).

**(c) Pre-Installation Submittal**

The Contractor shall prepare and submit to the Engineer the following for the micropile system or systems to be constructed. Work other than test pile installation shall not begin until the construction submittals have been received, reviewed, and accepted in writing by the Engineer.

- a. 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.
- b. 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 bond length
  5. Total micropile length
  6. Micropile top footing attachment
- c. If welding of casing is proposed, submit the proposed welding procedure, certified by a qualified welding specialist.
  - d. Information on headroom and space requirements for installation equipment that verify the proposed equipment can perform at the site.
  - e. Plan describing how surface water, drill flush, and excess waste grout will be controlled and disposed.
  - f. 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.
  - g. 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 the provisions for Grout Testing.
    5. Procedure and equipment for Contractor monitoring of grout quality.
  - h. 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 the provisions for Pile Load Tests.
  - i. 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.

**(d) Pre-installation Meeting:**

A pre-installation meeting will be scheduled by the Engineer and held prior to the start of micropile construction. The Engineer, Contractor,

micropile contractor, micropile designer, excavation contractor and geotechnical instrumentation specialist shall attend the meeting. Attendance is mandatory.

The pre-installation 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 various subcontractors especially those pertaining to excavation for micropile structures, anticipated subsurface conditions, micropile installation and testing, micropile structure survey control, and site drainage control.

**(e) Installation Records:**

The Engineer will prepare an installation record for each micropile. The Contractor shall assist the Engineer, as required, to obtain installation data. The records will include the following minimum information:

- a. Pile Identification
- b. Pile drilling start and finish times
- c. Existing ground surface elevation
- d. Top of Rock Elevation
- e. Bottom of Tremie Concrete Elevation
- f. Material Type below Tremie Concrete
- g. Final tip elevation
- h. Cut-off elevation
- i. Description of unusual installation behavior or conditions
- j. Grout pressures attained, if applicable
- k. Grout quantities pumped, including start and finish times
- l. Grout compression test results
- m. Pile materials and dimensions
- n. Reinforcing steel sizes and lengths
- o. Characteristics of all materials encountered during the drilling process, and their specific location(s) within the holes
- p. The location of special features such as mud seams, open cracks, broken rock, etc.
- q. Points where abnormal loss or gain to drill water has occurred
- r. Groundwater levels or other items of interest for grouting
- s. All significant actions of the bit
- t. If any weak material, such as coal, clay, weathered rock or the like is encountered within the required bond length, the hole shall be extended to compensate for the weak material.

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.

**Materials**

**(a) Water**

Water for mixing grout shall be in accordance with 913.01.

**(b) Admixtures**

Admixtures shall conform to the requirements of ASTM C494/AASHTO M194. Admixtures, which 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. Acceptance will be based on appropriate field tests. 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 and admixtures containing chlorides shall not be allowed.

**(c) Cement**

Portland cement shall be in accordance with 901.01(b), Type II and shall be the product of one manufacturer.

**(d) Centralizers and Spacers**

Centralizers and spacers shall be fabricated from schedule 40 PVC pipe or tube, steel, or material that is non-detrimental to the reinforcing steel. Wood shall not be used. Centralizers and spacers shall be:

- a. Securely attached to the reinforcement; sized to position the reinforcement within 3/8" of plan location from center of pile;
- b. Sized to allow grout tremie pipe insertion to the bottom of the drillhole; and
- c. Sized to allow grout to freely flow up the drillhole and casing and between adjacent reinforcing bars.

**(e) 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 0.031 in. The inside annulus between the reinforcing bars and the encapsulating tube shall be a minimum of 1/8" and be fully grouted with non-shrink grout.

**(f) Epoxy Coating**

The reinforcing bars shall be epoxy coated in accordance with 910.01(b)(9). Bend test requirements are waived. Bearing and nuts encased in the pile concrete footing need not be epoxy coated unless the footing reinforcement is epoxy coated.

**(g) Fine Aggregate**

Fine Aggregate shall be in accordance with 904.

**(h) Grout**

Neat cement or sand/cement mixture with a minimum 3-day compressive strength of 2,500 psi and a 28-day compressive strength of 5,000 psi in accordance with AASHTO T106/ASTM C109.

**(i) Grout Protection**

Provide a minimum 1 in. grout cover over bare or epoxy coated bars (excluding bar couplers) or minimum 0.5 in. grout cover over the encapsulation of encapsulated bars.

**(j) Pipe/Casing**

Casings shall be steel, smooth, clean, watertight, and of ample strength to withstand both handling and driving stresses and the pressure of both concrete and the surrounding earth materials. The outside diameter of casing shall not be less than the specified size of micropiles. All temporary casings shall be removed from micropile installations. Any length of permanent casing installed below the micropile cutoff elevation shall remain in place.

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:

- a. Shall meet the Tensile Requirements of ASTM A252, Grade 3, except the yield strength shall be a minimum of 50 ksi to 80 ksi as used in the design submittal. The Buy America Requirements of 106.01 shall be satisfied.
- b. Mill Secondary Casing shall not be allowed unless Buy America Requirements of 106.01 are satisfied, including providing Mill Certification.

For permanent casing/pipe that will be welded for structural purposes, the following material conditions apply:

- a. the carbon equivalency (CE) as defined in AWS D1.1, Section XI5.1, shall not exceed 0.45, as demonstrated by mill certifications
- b. the sulfur content shall not exceed 0.05%, as demonstrated by mill certifications

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

- a. the steel pipe shall not be joined by welded lap splicing
- b. welded seams and splices shall be complete penetration welds
- c. partial penetration welds may be restored in conformance with AWS D1.1
- d. the proposed welding procedure certified by a welding specialist shall be submitted for approval

Threaded casing joints shall develop at least the required compressive, tensile, and bending strength used in the design of the micropile.

**(k) Plates and Shapes**

Structural steel plates and shapes for pile tops attachments shall be in accordance with ASTM A36/AASHTO M183, or ASTM A572/AASHTO M223, Grade 50.

**(l) Reinforcing Bars**

All reinforcing steel shall be grade 60 or grade 75 deformed bars in accordance with 910.01 or ASTM A722/AASHTO M275, Grade 150. Where 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 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. Bar tendon coupler, if required, shall develop the ultimate tensile strength of the bars without failure. A Type A material certifications in accordance with 916 will be required.

**(m) Sheathing**

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

**Construction Methods and Equipment**

**(a) Site Drainage Control**

The Contractor shall control and properly dispose of drill flush and construction related waste, including excess grout, in accordance 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. 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.

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

**(b) Excavation**

Coordinate the work and the excavation so that 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 on the plans, except as stated herein, shall be made above or below the micropile structure locations without written approval of the Engineer.

**(c) Protection of Existing Utilities**

The Contractor shall control its operations to prevent damage to existing overhead and underground utilities. Preventive measures shall include, but not limited to, selecting construction methods and procedures that will prevent caving of the micropile boreholes.

**(d) Allowable Tolerances**

Centerline of piling shall not be more than 3 in. from indicated plan position. Pile alignment shall be within 2% of design alignment. Top elevation of pile shall be within +/- 1 in. of the design vertical elevation. Centerline of reinforcing steel shall not be more than 3/4 in. from indicated location. Micropiles not constructed within the required tolerances are unacceptable. The Contractor shall be responsible for correcting all unacceptable micropile installation to the satisfaction of the Engineer.

**(e) Installation**

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 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. The procedures shall not damage adjacent facilities or newly installed piles.

**(f) Drilling**

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 drilling equipment and methods shall provide an open borehole to the defined nominal diameter and full length, as shown on plans, prior to placing grout and reinforcement.

Temporary casing or other approved method of pile drillhole support will be required in caving or unstable ground to permit the pile 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.

**(g) Ground Heave or Subsidence**

During construction, the Contractor shall observe the conditions in the 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 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 movement or perform repairs.

**(h) Pipe Casing and Reinforcing Bar Placement and Splicing**

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 casing 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.

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

Centralizers, spaced not to exceed 10 ft, shall be provided on central reinforcement. The uppermost and lowermost centralizer shall be located 3 ft maximum from the top of the central reinforcement. Centralizers shall permit the free flow of grout without causing misalignment of the reinforcement. The central reinforcement steel with centralizers shall be lowered, not dropped, into the stabilized drillholes to the desired depth. The reinforcing steel shall be inserted into the drillholes to the desired depth. 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.

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 listed in this provision. 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 12 inches.

**(i) Grouting**

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. 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 verifiable means and methods of measuring the grout quality, quantity and pumping pressure during the grouting operations. Expansion additives in grout will not be allowed. Grout shall not be re-tempered or used after it has begun to set.

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 150 psi 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 drillhole 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 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 shall be filled with a 5,000-psi minimum compressive strength grout without voids from bottom to top of the micropile. The entire bond zone shall be completely filled with grout.

If the Contractor elects to use a postgrouting system, Working Drawings and details shall be submitted in the working drawings.

**(j) Grout Testing**

Grout within the micropiles shall attain a minimum compressive strength of 5,000 psi 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. The Contractor shall make two sets of six 2 in. cubes for each day of grouting (one set near the beginning of the day and one set near the end of the day) or for every 10 piles, whichever occurs more frequently. The Contractor shall test two cubes after 7 days cure, two cubes after 28 days cure, and keep two in reserve. Cubes shall be cured and tested according to ASTM C 109.

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. 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.

**(k) Micropile Installation Records**

The 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 provided by the Department. A separate log shall be provided for each micropile.

**(l) Pile Damage**

If a micropile is deemed unacceptable by the Engineer due to improper or inadequate construction or to damage caused by the Contractor, that micropile shall be load tested or replaced in a manner acceptable to the Engineer. Any

modification, which requires changes to the structure, shall have prior review by and the acceptance of the Engineer.

**(m) Obstructions**

Surface and subsurface obstructions at drilled pile locations shall be removed by the Contractor. Such obstructions may include manmade materials such as old concrete foundations and natural materials such as boulders. Special procedures and tools shall be employed by the Contractor after the hole cannot be advanced using conventional earth or rock augers, fitted with soil or rock teeth, drilling bucket and underreaming tools. Such special procedures/tools may include but are not limited to: chisels, boulder breakers, core barrels, air tools, hand excavation, temporary casing, and increasing the hole diameter in the overburden soils. Blasting shall not be allowed.

**(n) Lost Tools**

Drilling tools that are lost in the excavation shall not be considered obstructions and shall be promptly removed by the Contractor.

**(o) Cut-Off Lengths**

The tops of all permanent micropiles and pile casings shall be cut off at the elevation shown on the plans. All cut-off lengths shall become the property of the Contractor and shall be removed from the project site.

**Pile Load Tests**

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, tension load testing in accord with ASTM D3689, and lateral load testing in accord with ASTM D3966 (if required), except as modified herein.

**(a) Verification Load Tests**

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. Two sacrificial verification test piles shall be constructed in conformance with the approved Working Drawings. Verification test piles shall be installed at the following locations on the west edge of Abutment No. 2 and the East Edge of Abutment No. 1.

Verification load tests shall be performed to verify that the Contractor installed micropiles will meet the required compression and tension load capacities and load test acceptance criteria and to verify that the length of the micropile bond zone is adequate. The micropile verification load test results shall verify the Contractor's design and installation methods, and be reviewed and accepted by the Engineer prior to beginning installation of production micropiles.

The drilling-and-grouting method, casing length and outside diameter, reinforcing bar lengths, and depth of embedment for the verification test piles 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.

The maximum verification and proof test loads applied to the micropile shall not exceed 80 percent 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.

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 shall be performed on the same pile, the pile shall be tested under compression loads prior to testing under tension loads.

**(b) Testing Equipment and Data Recording.**

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 this provision.

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.

Apply and measure the test load with a hydraulic jack and pressure gauge. The pressure gauge shall be graduated in 72 psi 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.

Measure the pile top movement with a dial gauge capable of measuring to 0.001 in. 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. The details of the Testing equipment shall be included in the Working Drawings.

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

**(c) Verification Test Loading Schedule**

The micropile load test Design Load shall be taken as the maximum factored compression and tension loadings indicated on the Contract Plans.

The verification pile load tests shall be made by incrementally loading the micropile in accordance with the following cyclic load schedule for both compression and tension loading:

Step	Loading	Applied Load	Hold Time (min.)
1	Apply AL	AL	2.5
2	Cycle 1	0.17 DL	2.5
		0.33 DL	2.5
		0.50 DL	2.5
		AL	1
3	Cycle 2	0.10 DL	1
		0.21 DL	1
		0.32 DL	2.5
		0.43 DL	2.5
		0.54 DL	2.5
		0.64 DL	2.5
		0.75 DL	2.5
		AL	1
4	Cycle 3	0.20 DL	1
		0.40 DL	1
		0.60 DL	2.5
		0.80 DL	10 to 60 minutes
		1.00 DL	2.5
		AL	1
5	Cycle 4	0.25 DL	1
		0.50 DL	1
		0.75 DL	1
		1.00 DL	2.5
		1.25 DL	2.5
		1.50 DL	10
		1.13 DL	5
		0.75 DL	5
		0.38 DL	5
		AL	5

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. The verification test pile shall be monitored for creep at the 0.80 Design Load (DL). Pile movement during the creep test shall be measured and recorded at 1, 2, 3, 4, 5, 6, 10, 20, 30, 50, and 60 minutes. The alignment load shall not exceed 5 percent of the DL load. Dial gauges shall be reset to zero after the initial AL is applied.

The acceptance criteria for micropile verification load tests are:

1. The pile shall sustain the first compression or tension 0.75 DL test load with no more than ¼" total vertical movement at the top of the pile, relative to the position of the top of the pile prior to testing.

2. At the end of the 0.80 DL creep test load increment, test piles shall have a creep rate not exceeding 0.05 in./log cycle time (1 to 10 minutes) or 0.1 in./log cycle time (6 to 60 minutes or the last log cycle if held longer). The creep rate shall be linear or decreasing throughout the creep load hold period.
3. Failure does not occur at the 1.5 DL maximum test load. Failure is defined as load where the slope of the load versus head settlement curve first exceeds 0.002 in/kip.

The Engineer will provide the Contractor written confirmation of the micropile design and construction within 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.

Load tested micropiles and reaction piles located in non-production locations shall be cut 2 ft. below finished grade after completion.

**(d) Verification Test Pile Rejection**

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 be submitted as a revision to the working drawings and shall be stamped and signed by an Engineer Registered by the State of Indiana.

**(e) Proof Load Tests**

Perform proof load tests on the first set of production piles installed at each designated substructure unit prior to the installation of the remaining production piles in that unit. The first set of production piles is the number required to provide the required reaction capacity for the proof tested pile. The initial proof test piles shall be installed at Abutment No. 2 Proof testing shall be conducted at a frequency of 5% of the total number of micropiles. Location of additional proof test piles shall be as designated by the Engineer.

Any micropiles required for the reaction frame shall be included in the working drawings including any required strengthening.

**(a) Proof Test Loading Schedule**

Test piles designated for compression or tension proof load testing to a maximum test load of 1.60 times the micropile Design Load shown on the Plans or Working Drawings. Proof tests shall be made by incrementally loading the micropile in accordance with the following schedule, to be used for both compression and tension loading:

Step	Loading	Applied Load	Hold Time (min.)
1	Apply AL	AL	2.5
2	Load Cycle	0.09 DL	2.5
		0.18 DL	2.5
		0.27 DL	2.5
		0.36 DL	2.5
		0.45 DL	2.5
		0.54 DL	2.5
		0.63 DL	2.5
		0.72 DL	2.5
		0.80 DL	10 to 60 minutes
		0.90 DL	2.5
3	Unload Cycle	1.00 DL	2.5
		0.83 DL	4
		0.67 DL	4
		0.50 DL	4
		0.33 DL	4
		0.16 DL	4
		AL	4

Depending on performance, either a 10 minute or 60 minute creep test shall be performed at the 0.80DL Test Load. Where the pile top movement between 1 and 10 minutes exceeds 0.04 in., the Maximum Test Load shall be maintained an additional 50 minutes. Movements shall be recorded at 1, 2, 3, 5, 6, 10, 20, 30, 50 and 60 minutes. The alignment load shall not exceed 5 percent of DL. Dial gauges shall be reset to zero after the initial AL is applied.

The acceptance criteria for micropile proof load tests are:

1. The pile shall sustain the compression or tension 0.63 DL test load with no more than ¼" total vertical movement at the top of the pile, relative to the position of the top of the pile prior to testing.
2. At the end of the 0.80DL creep test load increment, test piles shall have a creep rate not exceeding 0.05 in./log cycle time (1 to 10 minutes) or 0.10 in./log cycle time (6 to 60 minutes). The creep rate shall be linear or decreasing throughout the creep load hold period.
3. Failure does not occur at the 1.60DL maximum test load. Failure is defined as load where the slope of the load versus head settlement curve first exceeds 0.002 in/kip.

**(b) Proof Test Pile Rejection**

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 a revision to the Working Drawings the Engineer's prior review and acceptance. Any modification that necessitates changes to the structure shall be submitted as a revision to the working drawings and shall be stamped and signed by an Engineer Registered by the State of Indiana.

**Method of Measurement**

Since payment will be made in lump sum, only those measurements necessary to verify design loads and bond lengths will be made.

**Basis of Payment**

This work will be paid for at the contract lump sum price for Micropiles.

Payment will be made under:

<b>Pay Item</b>	<b>Pay Unit Symbol</b>
Micropile.....	Lump sum
Micropile, Testing.....	Lump sum

The cost of Micropiles, including but not limited to design, working drawings, drilling, reinforcing steel, steel casing, grout, equipment, tools, labor transportation, operations, and other necessary incidentals required to provide the Micropile foundation system needed for the loadings shown in accordance with the bond zone as determined by the geotechnical report shall be included in the cost of micropile lump sum.

The cost of the Verification Testing and Proof Testing, including but not limited to sacrificial verification or proof test piles, testing equipment, modification of micropiles to accommodate the testing, modification of the micropiles to accommodate the testing loads and any other incidentals shall be included in the cost of Micropile, testing

The correcting of incomplete or unacceptable submittals shall be at no expense to the Department.

No extra compensation will be allowed for concrete required to fill an oversized casing or oversized excavation.

No extra compensation will be allowed for repair of damage caused by surface water.

The cost of remedial measures or repair work resulting from encountered unanticipated subsurface drainage structures will be included in a change order in accordance with 109.05.

Materials and work, including engineering analysis and redesigns, to correct out of tolerance micropile installations shall be included the cost of Micropile.

No payment will be made for providing corrective actions when the Contractor's methods of operations or failure to follow the specified or

approved construction sequence, as determined by the Engineer shall be at no additional cost.

Load testing and replacement of piles deemed unacceptable by the Engineer shall be at no cost to the Department.

All cost associated with the recovery of lost tools shall be at no cost to the Department.

No extra compensation will be allowed for an overrun of grout.

The cost to modify construction procedures, the cost of additional verification test piles, of additional proof load testing, and the cost of replacement of production micropiles shall be included in the cost of other items.