MICROPILES

**From Bennington ER BHF 010-1(45)

xx. DESCRIPTION. This work shall consist of constructing micropiles as shown in the Contract Documents.

xx. GENERAL REQUIREMENTS. The Contractor is responsible for furnishing, installing, and testing micropiles and pile top attachments for this project. The 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 Contractor shall design and install micropiles that will develop the load capacities indicated in the Contract Documents. The micropile load capacities shall be verified by verification load testing as required and shall meet the test acceptance criteria specified herein.

xx. MATERIALS. For all steel remaining as a permanent part of the work, Buy America Provisions pursuant to Subsection 107.22 shall apply.

Materials shall meet the following requirements:

(a) Permanent Casing. Permanent steel casing/pipe shall have the diameter and minimum wall thickness as specified by the Contractor's Professional Engineer. Permanent casing shall be of flush-joint or welded type and shall be of appropriate thickness to withstand the stresses associated with advancing it into the ground. The permanent steel casing/pipe shall conform to ASTM A 252, Grade 3, except the yield strength shall be a minimum of 345 MPa to 550 MPa (50 ksi to 80 ksi) as used in the design submittal, or may be new or unused American Petroleum Institute (API) 5CT (N80) steel pipe.

(1) Certification. Certification for permanent casing pipe shall meet the following requirements.

a. For permanent casing conforming to ASTM A 252, a Type D Certification shall be furnished in accordance with Subsection 700.02.

b. For permanent casing meeting API standards, the following Quality Control (QC) system and all QC activities shall be the responsibility of the Manufacturer/Supplier. The Engineer has the right to monitor any QC sampling and testing and to test any material or retained samples for specification conformance.

1. Quality Control. A "Plant Lot" of pipe in a raw material state shall be a maximum of 305 m (1000 linear feet). A random coupon sample shall be taken from every 75 m (250 feet) of casing from each plant lot. These coupons shall be tested for tensile strength, yield strength, elongation, and wall thickness. The minimum elongation shall be 15%. For casing

that will be welded, the testing shall also include sulfur content and carbon equivalency (CE) as defined in American Welding Society (AWS) D1.1, Section XI5.1. The sulfur content shall not exceed 0.05% and the CE shall not exceed 0.45. Results of the testing shall be submitted to the Engineer for approval.

Coupons shall be marked with an identification number which will be retraceable to the test certifications and which includes the VTrans contract number. All casing in a plant lot shall be marked along the tubular body of the casing with the same identification number prior to testing. The identification number shall appear on every piece of casing at no more than 3 m (10 foot) intervals.

If the Engineer determines the test results to be satisfactory, the approved plant lot may then be manufactured into the final product. Four random coupon samples taken from the "drops" during the manufacturing process shall be identified with the plant lot number and shipped to the job site with the finished casing.

The Contractor shall incorporate the following Quality Assurance (QA) system at the direction of the Engineer:

2. Quality Assurance. The "drops" shipped with the finished casing shall be tested by the Contractor, at an AMRL Accredited Laboratory, to identify the material properties outlined in Quality Control of this Section. The Engineer will review the test results prior to installation of the casing. If test results do not satisfy the criteria, coupons shall be taken from the lot at the job site. The requirement for testing of the "drops" may be waived at the discretion of the Engineer.

For each test result of the coupons taken from the lot at the job site found by the Engineer to be unsatisfactory, the rejected pieces shall be removed from the lot. An additional two test coupons shall be taken from the lot at the job site. If test results from either of these additional two test coupons are unsatisfactory, the entire plant lot is rejected. If satisfactory results are obtained, proceed as specified above.

VTrans may direct the Contractor to test any additional casing from the lot at the job site.

(2) Additional Requirements. Additional requirements for permanent casing that is installed in coupled (spliced) sections shall meet the following requirements:

a. The casing shall be flush joint and the pipe joint shall be completely shouldered with no stripped threads.

b. Welds shall meet the requirements of Subsection 506.10. The welding plan and procedures shall be approved by the VTrans Fabrication Supervisor.

(b) Bar Reinforcement. Bar reinforcement shall be Grade 420 or 520 (Grade 60 or 75), continuously threaded bar, meeting the requirements of AASHTO M 31M/M 31 (ASTM A 615/A 615M) or continuously threaded Uncoated High-Strength Steel Bars conforming to AASHTO M 275M/M 275 (ASTM A 722/A 722M), as used in the design submittal.

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

(c) Cement. Cement shall meet the requirements of Subsection 701.02.

(d) Grout. Grout shall be a neat cement or sand/cement mixture with minimum compressive strengths as used in the design submittal. Water for mixing grout shall be potable. The use of Grout Sand and Fly Ash in the mix is optional.

During production, micropile grout shall be tested by the Contractor for compressive strength in accordance with AASHTO T 106M/T 106 (ASTM C 109/C 109M) at a frequency of no less than one set of three 50 mm (2 inch) 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.

Grout consistency as measured by grout density shall be determined by the Contractor per AASHTO T 133 (ASTM C 188) 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 between 1.8 kg/m^3 and 1.9 kg/m^3 (110 lbs/ft^3 to 120 lbs/ft^3), or as used in the design submittal.

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.

(e) Centralizers and Spacers. Centralizers and spacers shall be fabricated from Schedule 40 PVC pipe, tube, steel, or material non-detrimental to the reinforcing steel. Wood shall not be used.

(f) Structural Steel. Structural steel shall meet the requirements of Subsection 714.02 or 714.03 as used in the design submittal.

xx. SUBMITTALS. The Contractor shall submit the following:

(a) Qualifications. The micropile Contractor shall be fully experienced in all aspects of micropile design and construction, and shall furnish all necessary plant, materials, skilled labor, and supervision to carry out the work under the contract. Submit the experience information outlined below to the Engineer for approval. This information shall be approved prior to any other work occurring under this specification. The Contractor shall allow 10 working days for the review of this material.

(1) Five projects in the past five years of similar scope and size to that indicated in the Contract Documents. A brief description of the scope of work and a reference shall be included for each project. As a minimum, the reference shall include an individual's name and current contact information. The micropile contractor shall not sublet the whole or any part of the work under the contract without the written approval of the Engineer.

(2) The proposed On-Site Supervisor for this work having supervised the successful installation of micropiles or soil tiebacks on at least five projects in the past five years. The proposed key personnel (Superintendent, Driller, and Project Engineer/Manager) who will be materially involved, with each having at least three years of relevant experience.

(b) Design and Installation Procedure. Submit the design and installation procedure information outlined below to the Engineer for approval. The Contractor shall allow 20 working days for the review of this material. Work shall not begin prior to receiving approval by the Engineer. Approval of the installation method by the Engineer does not constitute a guarantee of acceptable pile installations. Acceptable installations are the responsibility of the Contractor.

The micropiles shall be designed by a Professional Engineer (Structural or Civil) licensed in the State of Vermont, using FHWA's Micropile Design and Construction Reference Manual and the latest version of the AASHTO LRFD Bridge Design Specifications. The micropiles shall satisfy both structural and geotechnical requirements. The Contractor's Professional Engineer shall design the diameter, length, reinforcement, pile connections, grout strengths, and grouting pressures; select the equipment, procedures, and methods so that each pile meets the pile acceptance criteria, can support the ultimate tension and compression loads with combined bending moments and unbraced lengths, and meet other requirements indicated in the Contract Documents. The Contractor's Professional Engineer shall be responsible for the design, supervision, and reporting of the Verification Test Loading.

The design and details shall be signed, stamped, and dated by the Contractor's Professional Engineer.

The submitted design and installation procedure shall include the following information:

(1) Pile computations and details for each design capacity, including but not limited to grout-to-ground bond, piezometric levels, material unit weights and strength; nominal pile diameter, length, reinforcement, and pile connections; and post grout tube and grouting pressures.

(2) Proposed steel drill casing/pipe used as reinforcement. Pile computations shall account for the reduced area of the threaded joint in the structural design of the pile, particularly for the capacity in tension and bending. Identify any joint location restrictions that must be followed in construction. Pile computations shall account for 1.6 mm (1/16 inch) deduction in casing/pipe wall thickness as sacrificial material.

(3) Equipment for pile installation.

(4) Procedures for pile installation, including but not limited to installation sequence and the approximate time required for each sequence step.

(5) Procedures for advancing through boulders and other obstructions.

(6) Procedures for containment of drilling fluid and spoil, and disposal of spoil.

(7) Where applicable, drawings that show specific work can be performed under limited headroom conditions and as close to obstructions as site conditions warrant, to install the piles at the locations and pile batters indicated in the Contract Documents. Provide information on the length of the casing sections to be used, as dictated by the length of the drill mast and by the available overhead clearance, and the resulting location of joints. Welding procedures for all shop and/or field welds shall be submitted.

(8) Procedures and equipment for placing grout.

a. Prepare the mix design for the grout and obtain documentation from an AMRL accredited laboratory showing the following:

1. The mix design conforms to the submitted mix and meets the strength requirements specified by the Contractor's Professional Engineer.

2. The compressive strength of the mix, tested at 3, 7, 14, and 28 days.

3. The specific gravity of the mix.

b. Identify a method for monitoring quality control of the mix. At a minimum, the Contractor shall use a Baroid Mud Balance per American Petroleum Institute (API) Recommended Practice (RP) 13B-1: Standard Procedure for Testing Water-Based Drilling Fluids, to check the specific gravity of the mixed grout prior to placement of the grout into each micropile.

c. Provide pressure gages capable of measuring the actual grout pressures used and such that actual pressure readings are within the middle third of the gage.

(9) Post-grouting equipment and procedures, including the method, sequence of operations, and equipment required.

(10) Layout drawings showing the proposed sequence of pile installation. Coordinate this sequence with the proposed phasing and scheduling. Layout drawings should include micropile number, design load for each pile, type and size of bar reinforcement, minimum total bond length, total micropile length, and the pile top attachment details.

(11) Description of test setup and jack, pressure gauge, and load cell calibration curves. Equipment calibration test reports shall be provided for each test jack, pressure gauge and master pressure gauge, and electronic load cell to be used. The test equipment shall have been calibrated within 90 calendar days of the date submitted by an independent testing firm.

(c) Record Information. Submit revisions to the design and installation procedure information outlined in part (b) of SUBMITTALS of this Section to the Engineer as required within 60 days from completion of micropile installation.

xx. CONSTRUCTION REQUIREMENTS.

(a) Drilling and Excavation. Progress all micropiles using steel drill casing. The hole shall be advanced using a duplex drilling method without drilling or flushing ahead of the drill casing by more than 300 mm (1 foot). Drilling and excavation shall be performed in such a manner as to prevent collapse of the hole. Use of bentonite slurry is not permitted. Use of polymer slurry to remove cuttings from the cased hole shall be approved by the Engineer.

The boring logs included in the Contract Documents indicate that several boulders and cobbles were encountered during the subsurface investigation. An obstruction is defined as something encountered while advancing a micropile that is not expected based on boring log findings or known obstructions identified on the Plans. Boulders, cobbles, and very dense till material are not considered obstructions. When cobbles, boulders, or obstructions are encountered during excavation for a pile, the hole shall be advanced by means of coring, a tricone roller bit,

or other tooling approved by the Engineer. Use of drop-type impact hammers and blasting are not permitted. Use of down-the-hole hammers shall be approved by the Engineer.

Procedures and operations shall be controlled so as to prevent undermining, damage, or settlement to adjacent structures, tunnels, utilities, or adjacent ground. All drilling operations shall be discontinued at the first sign of undermining, damage, or settlement and a written plan shall be provided to the Engineer for review with procedures to avoid reoccurrence. Work shall be resumed only after the Engineer has approved the plan in writing. All damage and settlement shall be repaired at no additional cost to VTrans.

The rate of fluid flow used to progress the holes shall be monitored. Drilling fluid shall be controlled and spoils shall be disposed of in accordance with the approved procedures.

Holes shall not be progressed, pressure-grouted, or post-grouted, within a radius of 1.5 meter (5 feet) of a micropile until the grout for that micropile has set for 24 hours.

The drill hole shall be open along its full length to at least the design minimum diameter prior to grout placement.

(b) Reinforcement and Post Grout Tube Placement. Centralizers sized to position the reinforcement within 10 mm (3/8 inch) of plan location from the center of the pile shall be provided. The centralizers shall be sized to allow grout tremie pipe insertion to the bottom of the drill hole and to allow grout to freely flow up the drill hole and casing. The centralizers shall be securely attached to the reinforcement to withstand installation stresses. Centralizers shall be provided at centers not to exceed 3 m (10 foot) spacing. Micropile reinforcement shall not be dropped into the hole. When a post grout tube is used, it shall be attached to the steel reinforcement prior to lowering it into the hole.

(c) Grout Placement and Casing Removal. The Contractor shall perform grout testing in accordance with part (d) of MATERIALS of this Section.

Grout shall be placed by means of a tremie pipe from the bottom of the pile upward. The initial volume of grout required to fill the hole shall be recorded along with the grouting pressure and volume of grout being pumped into the pile during pressure grouting. Upon completion, the grout level shall be maintained at or above the pile cut-off elevation until the grout has set.

The grout pressure and volume measuring gages at the pile installation site shall be accessible and legible to the inspector during the grouting operations.

(d) Construction Tolerances. Piles shall be installed so that the center of each micropile does not vary from the location indicated in the Plans by more than 75 mm (3 inches). Micropiles shall not vary from the vertical or established batter by more

than 6 mm per 300 mm (1/4 inch per foot), as measured above ground.

(e) Testing. Compression load testing shall be conducted in accordance with ASTM D 1143, except as modified herein. Tension load testing shall be conducted in accordance with ASTM D 3689, except as modified herein.

Verification load test pile(s) shall be installed at a location approved by the Engineer. The test pile shall not be a production pile. The Contractor shall perform the verification test on a micropile of the same diameter and cased length as the production piles. The uncased length shall be determined so that the test loads applied to the micropile result in an accurate determination of the nominal grout to soil bond strength in the bond zone. Test loads shall not exceed 80 percent of the structural capacity of the micropile structural elements; including steel yield in tension, steel yield or buckling in compression, or grout crushing in compression.

Testing equipment shall include dial gauges, a dial gauge independent reference frame, jack and pressure gauge, electronic load cell (with readout device), 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 subpart (b)(11) of SUBMITTALS of this Section.

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 690 KPa (100 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 test 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 pair of dial gauges capable of measuring to 0.025 mm (0.001 inch). The dial gauges shall have a travel sufficient to allow the test to be done without having to reset the gauges. Visually align the frame to be parallel with the axis of the micropile and support the gauges independently from the jack, pile, or reaction frame.

Test verification pile(s) to a maximum test load of 2.5 times the maximum compressive or tensile resistance specified, hereafter termed “Design Test Load” shown on the Plans. The verification

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

Verification Test Loading Schedule		
AL = Alignment Load DTL = Design Test Load		
	LOAD	HOLD TIME
1	AL (0.05 DTL)	1 minute
2	0.25 DTL	1 minute
3	0.50 DTL	1 minute
4	AL	1 minute
5	0.25 DTL	1 minute
6	0.50 DTL	1 minute
7	0.75 DTL	1 minute
8	AL	1 minute
9	0.25 DTL	1 minute
10	0.50 DTL	1 minute
11	0.75 DTL	1 minute
12	1.00 DTL	1 minute
13	AL	1 minute
14	0.25 DTL	1 minute
15	0.50 DTL	1 minute
16	0.75 DTL	1 minute
17	1.00 DTL	1 minute
18	1.33 DTL	60 minutes
19	1.75 DTL	1 minute
20	2.00 DTL	1 minute
21	2.25 DTL	1 minute
22	2.50 DTL	10 minutes
23	2.00 DTL	1 minute
24	1.00 DTL	1 minute
25	0.50 DTL	1 minute
26	AL	1 minute

The test load shall be applied in increments of 25 percent of the DTL. 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. The verification test pile shall be monitored for creep at the 1.33 DTL. Pile movement during creep test shall be measured and recorded at 1, 2, 3, 4, 5, 6, 10, 20, 30, 50, and 60 minutes. The AL shall not exceed 5 percent of the DTL. Dial gauges shall be reset to zero after the initial AL is applied.

The acceptance criteria for micropile verification load test are:

(1) The tolerable movement during the load test at the top of the micropile shall be 13 mm (0.5 inch), unless otherwise directed by the Engineer.

(2) At the end of the 1.33 DTL creep test load increment, test piles shall have a creep rate not exceeding 1.27 mm/log

cycle time (0.05 inch/log cycle time) (1 to 10 minutes) or 2.54 mm/log cycle time (0.1 inch/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 any load increment up to and including the 2.5 DTL maximum test load. Failure is defined as load where the slope of the load versus head settlement curve first exceeds 0.178 mm/KN (1/32 inch/kip).

Upon completion of the test, the Contractor's Professional Engineer shall provide, to the Engineer, a written summary of the verification test results and a comparison of the results with the individual acceptance criteria above. The load test data will provide the opportunity to confirm the micropile design assumptions and installation methods as used in the design submittal. The Contractor shall allow 5 working days for the review of this material. The Engineer will either confirm the capacities and bond lengths specified in the design submittals or reject the pile(s) based upon the verification test results.

Adjustment of the micropile lengths may be made by the Contractor's Professional Engineer on the basis of the load test results. If the verification test micropile fails to meet the acceptance criteria, the Contractor's Professional Engineer 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. At the completion of verification testing, test piles shall be removed down to the elevation specified by the Engineer.

(f) Pile Acceptance Criteria. Pile(s) shall be accepted if all of the following criteria are met:

(1) Pile meets Construction Tolerance criteria.

(2) Pile meets the MATERIALS requirements of this Section and was installed in accordance with the approved submittal.

(3) Pile is not damaged.

(4) Pile was installed using the same method, grout volumes, and pressures as the accepted test pile, if applicable.

(g) Unacceptable Piles. Unacceptable piles are piles which do not meet the acceptance criteria identified in part (f) above.

A written plan shall be submitted to the Engineer for remedial action, indicating how to correct the problem and prevent its reoccurrence. Unacceptable piles shall be repaired, augmented, or replaced in accordance with the approved remedial plan at no additional cost to VTrans.

xx. METHOD OF MEASUREMENT. The quantity of Special Provision (Micropile) will be the number of micropiles installed, at the locations specified in the Contract Documents, in the complete and accepted work.

The quantity of Special Provision (Micropile Verification Load Test) will be the number of load tests performed in the complete and accepted work.

If a test pile is installed outside of foundation limits, no measurement for payment as Special Provision (Micropile) will be made for the test pile.

The quantity of Special Provision (Furnishing Equipment for Installing Micropiles) to be measured for payment will be on a lump sum basis in the complete and accepted work.

xx. BASIS OF PAYMENT. The accepted quantity of Special Provision (Micropile) will be paid for at the Contract unit price per each. Payment will be full compensation for providing all required submittals; for designing, furnishing, transporting, storing, handling, and placing the materials specified, including but not limited to permanent casing, bar reinforcement, grout, centralizers, spacers, and pile top attachment; and for furnishing all labor, tools, equipment, and incidentals necessary to complete the work.

The Contractor shall be responsible for estimating the grout take. There will be no extra compensation allowed for grout overruns.

The accepted quantity of Special Provision (Micropile Verification Load Test) will be paid for at the Contract unit price per each. Payment will be full compensation for furnishing and mobilizing the required equipment to perform a verification load test, including erecting and dismantling the test setup, and for furnishing all labor, tools, equipment, and incidentals necessary to complete the work.

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.

Payment for furnishing and installing test piling installed outside of foundation limits, and/or not subsequently accepted as permanent foundation piling, will be included in the unit price bid for Special Provision (Micropile Verification Load Test).

The accepted quantity of Special Provision (Furnishing Equipment for Installing Micropiles) will be paid for at the Contract lump sum price. Payment will be full compensation for furnishing and mobilizing to the project site all equipment required for installing the micropiles, operating and maintaining the equipment while in service on the project, and demobilizing the equipment from the project site.

When the equipment for installing the micropiles, including drill rig, grout pump, and material, has been set up and installation of production piles has started, a payment of 50 percent of the Contract lump sum price will be allowed. The remaining 50 percent of the Contract lump sum price will be paid when the micropile installations are complete and the equipment has been removed from the site to the satisfaction of the Engineer.

Payment will be made under:

Pay Item		Pay Unit
900.620	Special Provision (Micropile)	Each
900.620	Special Provision (Micropile Verification Load Test)	Each
900.645	Special Provision (Furnishing Equipment for Installing Micropiles)	Lump Sum