

DRILLED SHAFTS

****From Cambridge BRF 027-1(4)/STP 030-2(27)**

- xx. DESCRIPTION. This work shall consist of mobilizing and furnishing all materials, equipment, labor, and services necessary to construct production drilled shafts in accordance with these provisions, the Plans, and as directed by the Engineer.
- xx. GENERAL REQUIREMENTS. The lengths of the drilled shafts shown on the Plans have been estimated from the available subsurface information. The Contractor is expected to furnish the proposed drilled shafts as per Plan requirements with the understanding that the actual length required based on actual conditions encountered during construction may differ from the estimated length shown in the Plans.

This work shall be conducted in strict conformance with all applicable environmental regulations and permits. The Contractor/subcontractor performing this work must be prequalified in accordance with PREQUALIFICATION of this Section.

The drilled shaft Contractor is responsible for all aspects of construction of drilled shafts. This includes excavation, reinforcing steel, and concrete placement.

Prior to submitting a bid for the drilled shaft construction, it is strongly encouraged that the drilled shaft Contractor (hereafter "Contractor" for the purposes of this Section) visits the site where drilled shafts will be used on this project.

- xx. DEFINITIONS.

CASING METHOD - A method of shaft construction, consisting of advancing and cleaning a cased hole, placing the reinforcing cage, and placing concrete in the shaft while extracting temporary casing.

CASING (SHELL) - A steel casing used to construct the drilled shaft. The casing can help advance the hole and supports the sides of the hole.

DRILLED SHAFT - A cylindrical structural column transmitting loads to soil and/or rock. The drilled shaft is constructed in a hole with a circular cross section. The hole is filled with concrete and may be reinforced with steel.

DRY CONSTRUCTION METHOD - A method of shaft construction consisting of drilling the shaft, removing water and material from the excavation, placing the reinforcing cage, and placing concrete in the shaft in a relatively dry condition.

OBSTRUCTIONS - Obstructions may include man-made and/or man-placed materials and natural materials, such as boulders, that require the use of special procedures and/or tools by the Contractor when the hole cannot be advanced using conventional augers, drilling buckets, and/or underreaming tools or reverse circulation drilling (if this is used as the primary drilling method). Such special procedures/tools may include but are not limited to chisels, boulder breakers, core barrels, air tools, hand excavation, temporary casing, and increasing hole diameter. Surface and subsurface obstructions at drilled shaft locations shall be removed by the Contractor. Drilling tools that are lost in the excavation shall not be considered obstructions and shall be promptly removed by the Contractor without compensation.

Surface rip-rap and boulders shall not be considered an obstruction. When suspected obstructions are encountered, the Contractor shall notify the Engineer and recommend a course of action to advance the drill hole in an expedient manner. The Engineer shall determine if an obstruction has been encountered.

SLURRY - A mixture of water and bentonite, or water and polymers, which provides hydrostatic pressure that supports the sides and bottom of the hole, lubricates and cools the drill tools, and aids clean out. Slurry cannot be made from native materials, or material from the excavation.

SURFACE CASING - Temporary casing installed to prevent sloughing of the surrounding soil near the surface of the shaft excavation.

TEMPORARY CASING - A casing that serves its function during construction of the drilled shafts. It serves no permanent structural function, and shall be removed in the final condition.

PERMANENT CASING - A casing that will be left in place after construction. The permanent casing will be used to protect the upper portions of the drilled shaft.

WET CONSTRUCTION METHOD - A method of shaft construction consisting of using water or slurry to maintain stability of the hole while advancing the excavation to the final depth, placing the reinforcing cage, and placing concrete in the shaft.

xx. MATERIALS.

- (a) Drilled Shaft Concrete. Concrete for drilled shafts shall meet the requirements of Section 501 for HP Class SCC, with the exception that the 56 day permeability test is not required.

The proposed aggregate gradations for drilled shaft concrete may differ from those specified in Subsections 704.01 and 704.02, but shall meet the requirements of ASTM C 33 or AASHTO M6/M80. Maximum aggregate size is 12.5 mm (1/2").

- (b) Reinforcing Steel. Reinforcing steel shall conform to Section 507. Centralizers used to provide the required sidewall and bottom clearance for the reinforcement shall be constructed of an approved non-corrosive material that is compatible with and as durable as the shaft concrete. The Engineer shall approve the type of centralizers prior to use.
- (c) Steel Casing for Drilled Shafts. Steel casing shall meet the requirements of ASTM A252 Grade 2. Casings shall have inside diameters not less than the indicated shaft sizes. However, the Contractor may increase the size of the casing by 150 mm (6") (larger increases require approval of the Engineer) to facilitate construction operations, at no additional cost to the Agency. Casings shall have a 16 mm (5/8 inch) minimum wall thickness and have sufficient strength to withstand handling stresses, concrete pressures, and surrounding earth or fluid pressures. It is the Contractor's responsibility to determine the final wall thickness necessary to meet these requirements. No appurtenances, reinforcement, or holes shall be added to the casing without the approval of the Engineer.
- (d) Mineral Slurry. Provide mineral (bentonite) slurry that will remain in suspension, and with sufficient viscosity and gel characteristics to transport excavated material to a suitable screening system. Provide slurry with the percentage and specific gravity of the material used to make the suspension sufficient to maintain the stability of the excavation and allow proper concrete placement.

The acceptable ranges of values for mineral slurry are as follows:

RANGE OF VALUES FOR MINERAL SLURRY (at 20 °C, 68 °F)

Property (Units)	Test*	Requirement
Density (kg/m ³)	Mud Weight (Density) API 13B-1, Section 1	1030 to 1153**
Viscosity (sec/qt)	Marsh Funnel and Cup APT 13b-1, Section 2.2	28 to 50
pH	Glass Electrode, pH Meter or pH Paper	8 to 11
Sand Content (%) immediately prior to placing concrete	Sand Content Test API 13B-1, Section 5	4.0 max

* These tests shall be performed in accordance with the American Petroleum Institutes RP 13B-1, Recommended Practice for Field Testing Water Based Drilling Fluids.

**Unit weights stated are exclusive of weighting agents that may be proposed by the Contractor with the agreement of the slurry manufacturer's representative and the Agency.

De-sand the slurry in order that the sand content does not exceed 4 percent (by volume) measured 300 mm (1 foot) from bottom of shaft prior to concrete placement. All referenced tests shall be conducted by the Contractor with results presented to the Engineer. All necessary equipment and materials shall be provided by the Contractor.

- (e) Polymer Slurry. Provide polymer slurry with sufficient viscosity and gel characteristics to hold the hole open and to transport excavated material to a suitable screening system. Polymer slurry (vinyl (dry) or natural polymers) shall be made from Partially-Hydrolyzed Polyacrylamide Polymer (PHPA) (emulsified). The polymer slurry product must be approved for use by the Agency.

Slurry properties at the time of mixing and at the time of concreting must be in conformance with the written recommendations of the manufacturer. The use of a blended mineral-polymer slurry is not permitted.

The acceptable range of values for polymer slurry is as follows:

RANGE OF VALUES FOR POLYMER SLURRY (at 20 °C, 68 °F)

Property (Units)	Test*	Requirement
Density (kg/m ³)	Mud Weight (Density) API 13B-1, Section 1	1025 max
Viscosity (sec/qt)	Marsh Funnel and Cup APT 13b-1, Section 2.2	32 to 135
pH	Glass Electrode, pH Meter or pH Paper	8 to 11.5
Sand Content (%) immediately prior to placing concrete	Sand Content Test API 13B-1, Section 5	1.0 max

* These tests shall be performed in accordance with the American Petroleum Institutes RP 13B-1 Recommended Practices for Field Testing Water Based Drilling Fluids.

De-sand the polymer slurry in order that the sand content is less than 1 percent (by volume) prior to concrete placement. All referenced tests shall be conducted by the Contractor with results presented to the Engineer. All necessary equipment and materials shall be provided by the Contractor.

- (f) Access Tubes for Cross-Hole Sonic Log Testing. Access tubes for Cross-Hole Sonic Log (CSL) testing shall be steel pipe of 3.7 mm (0.145 inch) minimum wall thickness and at least 38 mm (1½ inches) inside diameter. The access tubes shall have a round, regular inside diameter free of defects and obstructions, including all pipe joints, in order to

permit the free, unobstructed passage of 33 mm (1.3 inches) maximum diameter source and receiver probes used for the CSL tests.

The access tubes shall be watertight and free from corrosion with clean internal and external faces to ensure good bond between the concrete and the access tubes. The access tubes shall be fitted with watertight caps on the bottom and the top.

- (g) Grout. The access tubes for CSL tests shall be grouted after the completion of the test. The grout for filling the access tubes at the completion of the CSL tests shall conform to Subsection 707.03.
- (h) Water. Provide water conforming to the requirements of Section 745, except with a pH conforming to the slurry requirements listed above.

xx. PREQUALIFICATION. The Contractor shall submit proof and details of the following:

- (a) Three projects in the past five years where the Contractor or subcontractor performing the work has successfully installed drilled shafts of similar diameter and length as required for this project, and a minimum of one project requiring similar on-site topographical and geotechnical conditions to those described in the Plans.
- (b) The on-site Superintendent shall have a minimum of two years experience in supervising construction of drilled shaft foundations of similar size (diameter and depth) and difficulty to those shown on the Plans, and in similar geotechnical conditions. The work experience shall be direct supervisory responsibility for the on-site drilled shaft construction operations. Project management level positions indirectly supervising on-site drilled shaft construction operations shall not be considered to be acceptable for this experience requirement.
- (c) The drill operators having had a minimum of one year of experience installing drilled shafts with similar diameters and lengths, and in similar conditions. Include details describing the equipment and methods used, difficulties encountered and how they were overcome, and the results of any testing performed. For each project cited, include the name and telephone number of someone who can be contacted as a reference.

The Contractor shall submit this information to the Engineer for review, evaluation, and approval prior to submitting detailed information as required under SUBMITTALS AND PRECONSTRUCTION REQUIREMENTS of this Section. The Engineer will render a decision within 10 working days after receipt of the submission. The Contractor or subcontractor will not be permitted to install drilled shafts without this approval.

The Engineer may suspend the drilled shaft construction if the Contractor substitutes unapproved field personnel without prior approval by the Engineer. The Contractor shall be fully liable for the additional costs resulting from the suspension of work and no adjustments in contract time resulting from such suspension of work will be allowed.

xx. SUBMITTALS AND PRECONSTRUCTION REQUIREMENTS.

- (a) Submittals. All approvals are subject to satisfactory field performance. Approval of a submittal does not relieve the Contractor and/or subcontractor of their responsibilities to satisfactorily complete the work detailed in the Contract Documents. If the approved submittal procedures do not produce satisfactory field performance, the Contractor will be responsible for submitting revised procedures. No further drilled shaft work will be allowed until the revised procedures have been approved.

The Contractor shall submit a Drilled Shaft Installation Plan (hereafter "plan" for the purposes of this Section) to the Engineer for review and approval prior to commencing the work. The plan shall document the proposed procedures and equipment for installing drilled shafts. The Engineer will render a decision within 15 working days from the date of receipt of all required information. The submittal shall include, but not be limited to, the following information:

- (1) A list, description, and capacities of proposed equipment and procedures for drilled shaft installation, including drawings showing consecutive steps of drilled shaft installation and drawings with measurements showing that the proposed equipment can perform the specified work. Included in the drawings shall be sketches that show the areas that are planned to be used for staging, layout drawings showing the proposed sequence of drilled shaft installation, and detailed drawings of all over-water equipment for drilled shaft installation. The information shall describe the type of equipment to be used, including drill rig, cranes, drilling tools, final cleaning equipment, de-sanding equipment, slurry pumps, bailing buckets, sampling equipment, tremies or concrete pumps, and casing, including casing dimensions, material and splice details, etc. As appropriate, the narrative shall describe equipment suitability to the anticipated site and subsurface conditions. The narrative shall include a project history of the drilling equipment demonstrating the successful use of the equipment on shafts of equal or greater size in similar subsurface conditions. Provide a detailed description of procedures for temporary and permanent casing installation and removal as applicable.

- (2) Details of shaft excavation methods, including removal of sediment from the shaft bottom. Details of proposed methods to clean the shaft after initial excavation. Details of proposed methods to check shaft bottom cleanliness. Procedures for control, removal, and disposal of spoils. Where casing is proposed or required, casing dimensions and detailed procedures for permanent casing installation and temporary casing installation and removal shall be provided.
- (3) Details of the method(s) to be used to ensure drilled shaft hole stability (i.e. prevention of caving, bottom heave, etc., using temporary casing, slurry, or other means) during excavation and concrete placement. The details shall include a review of method suitability to the anticipated site and subsurface geotechnical conditions.
- (4) Shaft excavation methods, and verification methods of final shaft dimensions and verticality. Include details of proposed corrective measures to be implemented as necessary.
- (5) Methods of removal and disposal of contaminated concrete.
- (6) Details of steel reinforcement lifting, splicing, insertion, and securing, including support and centralization methods.
- (7) Details of concrete batching and/or delivery to the site, how concrete acceptance samples will be collected, proposed location for concrete acceptance testing, and concrete placement including proposed operational procedures for concrete pump or tremie. Include details of initial placement, raising tremie pipe(s) during placement, and overfilling of the shaft concrete, the method to accurately monitor the volume of concrete being placed at all times during the pour, and provisions to prepare the completed shaft top at its final shaft top elevation.
- (8) Approved concrete mix design in accordance with MATERIALS of this Section.
- (9) Slurry Technical Assistance. If slurry is used to construct the shafts, the Contractor shall provide, or arrange for, technical assistance from the slurry manufacturer as specified in this Specification. The submittal shall include the following:
 - a. The name and current phone number of the slurry manufacturer's technical representative assigned to the project.
 - b. The name(s) of the Contractor's personnel

assigned to the project and trained by the slurry manufacturer's technical representative in the proper use of the slurry. The submittal shall include a signed training certification letter from the slurry manufacturer for each individual, including the date of the training.

- (10) Detailed procedures for mixing, using, maintaining, and disposing of the slurry shall be provided. A detailed mix design (including all additives and their specific purpose in the slurry mix), and a discussion of its suitability to the anticipated subsurface geotechnical conditions, shall also be provided for the proposed slurry.
- (11) The submittal shall include a detailed plan for quality control of the selected slurry, including tests to be performed, test methods to be used, and minimum and/or maximum property requirements which must be met to ensure that the slurry functions as intended, considering the anticipated subsurface conditions and shaft construction methods, in accordance with the slurry manufacturer's recommendations and these Specifications.
- (12) Description and details of the slurry sampling tool to be used. Provide a tool capable of taking a slurry sample at a specific depth, without being contaminated by slurry from another depth.
- (13) If slurry is to be used, an alternate procedure to be used which will secure the shaft in the event of slurry loss or loss of slurry stabilization properties.
- (14) Description of the type of feet to be used to support the reinforcing steel cage in the drilled shaft.
- (15) Emergency construction joint procedure, to be used when concrete placement for the drilled shaft is unexpectedly interrupted.
- (16) Description of equipment and method to be used for drilled shaft inspection. The Inspector will use these methods and equipment to inspect the drilled shafts. The inspection program must be thorough enough to assure the Engineer that each drilled shaft meets the requirements of these provisions.
- (17) Method for reinsertion of a tremie pipe, if required.
- (18) Details of equipment and procedures for obstruction removal, including the types of chisels and grabs.
- (19) Method used to fill or eliminate all voids below the top of shaft between the plan shaft diameter and

excavated shaft diameter, or between the shaft casing and surrounding soil, where permanent casing is specified.

The Engineer will evaluate the plan for conformance with the Contract Documents. Any part of the plan that is unacceptable will be rejected and the Contractor shall submit changes agreed upon for reevaluation. The Engineer will notify the Contractor within seven working days after receipt of proposed changes of their acceptance or rejection. All approvals given by the Engineer shall be subject to trial and satisfactory performance in the field.

Actual drilled shaft location data shall be submitted to the Engineer within one working day after a drilled shaft is installed. The Contractor shall provide the Engineer's on-site representative with written tabulations of the following information:

- (1) Drilled shaft location.
- (2) Elevation of top of drilled shaft measured to the nearest 12 mm (1/2 inch).
- (3) Deviation from design plan location measured to the nearest 6 mm (1/4 inch).
- (4) Plumbness (deviation from vertical) as determined along the entire length of the shaft where required.

Within ten calendar days after the completion of installation of all drilled shafts, and before removing the drilled shaft installation equipment from the site, the Contractor shall provide the Engineer with a plan showing the as-installed location of all drilled shafts installed to the tolerances specified in the Contract Documents.

- (b) Drilled Shaft Pre-Construction Meeting. A meeting shall be held after the approval of the submittal detailing the installation procedure, but prior to commencing construction of the drilled shafts. The purpose of the meeting will be to review all aspects of the drilled shaft construction and testing and to facilitate coordination between all parties involved.

Individuals attending the meeting representing the Agency shall include the Engineer, the Project Manager, the Design Engineer, the Structural Concrete Engineer, the Soils and Foundation Engineer, and the Geologist.

Individuals attending the meeting representing the Contractor and subcontractor shall include the project Superintendent and all foremen in charge of excavating the shaft, placing casing and slurry, placing reinforcing steel, and placing the concrete. A representative from the concrete producer shall also attend the meeting. If slurry is to be used, the slurry manufacturer shall be available

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by phone for technical assistance during this meeting. All parties shall be notified a minimum of 7 days in advance of the meeting date.

(c) Production Shaft Installation Sequencing and Scheduling.

- (1) Drilling, installation of reinforcing steel, and concreting shall be scheduled so that each drilled shaft is poured immediately after drilling is complete, the shaft is inspected and accepted by the Engineer, and reinforcing steel placed and accepted.
- (2) The Contractor will not be permitted to schedule a concrete pour until it is demonstrated that the Contractor can achieve the required bottom of hole cleanliness to the satisfaction of the Engineer.
- (3) Vibration or excessive wheel loads will not be allowed within the immediate vicinity of any drilled shaft. Maintain a stable shaft excavation at all times.

xx. CONSTRUCTION TOLERANCES. In-place tolerances for drilled shafts shall be as follows:

- (a) The top of shaft shall not vary horizontally from the location shown on the Plans by more than 75 mm (3 inches).
- (b) The allowable tolerance from the required verticality is 2%. This tolerance applies for the total length of shaft.
- (c) The top of shaft elevation shall be within 25 mm (1 inch) above or 75 mm (3 inches) below the elevation shown in the Plans.
- (d) Reinforcing steel projection elevation tolerance, after all shaft concrete has been placed, is ± 50 mm (± 2 inches) from the projection elevation shown in the Plans.
- (e) Tolerances for the diameter are as follows: The minimum diameter of the drilled shaft is not more than 25 mm (1 inch) less than the diameter shown on the Plans. The maximum shaft diameter is the diameter shown on the Plans plus 150 mm (6 inches).

Drilled shaft excavations and completed shafts not constructed within the required tolerances are unacceptable. The Contractor shall submit written correction procedures to the Engineer for approval prior to correcting the deficiencies. The Contractor is responsible for correcting all unacceptable shaft excavations and completed shafts to the satisfaction of the Engineer at no cost to the Agency and without extension of the Contract Completion Date.

xx. CONSTRUCTION REQUIREMENTS.

- (a) Furnishing Equipment for Drilled Shaft Construction. The

type and size of the equipment for constructing drilled shafts shall be approved by the Engineer prior to being moved onto the project. When directed by the Engineer, unsatisfactory equipment shall be removed from the project and replaced with satisfactory equipment.

- (b) Drilling and Excavation. The Contractor shall perform the excavations required for the shafts, through whatever materials are encountered, to the dimensions and elevations shown in the Plans or otherwise required by the Contract Documents. The Contractor shall extend the drilled shaft base elevations when the Engineer determines that the material encountered during the excavation is unsuitable and/or differs from that anticipated in the design of the drilled shaft. The Contractor's methods and equipment shall be suitable for the intended purpose and materials encountered.

The Contractor shall excavate the holes and dispose of all excavated material for drilled shafts using the same requirements, methods, procedures, and equipment approved by the Engineer. The Contractor shall not alter equipment and/or methods without written permission from the Engineer.

Pre-excavation, utilizing appropriate sediment and turbidity controls when in/near waters of the State, may be needed to advance past shallow obstructions before installing casing.

- (c) Slurry. The drilled shafts may be advanced using a controlled slurry or water to maintain the excavation. A temporary surface casing shall be used above the top of shaft elevation extending above the adjacent water level. The fluid level inside the hole shall be maintained above the adjacent water level at all times during installation and cleaning out.

Pre-mix the slurry, and allow adequate time for hydration prior to introduction into the shaft excavation. Provide adequate slurry tanks when specified or required by the Engineer. Do not mix slurry in the hole for the drilled shaft. Slurry pits will not be allowed without written permission from the Engineer.

Provide adequate de-sanding equipment where required for slurry operations. Take appropriate steps to prevent slurry from setting up in the shaft excavation, such as agitation, circulation, and adjusting the properties of the slurry. Do not let bentonitic slurry sit unagitated for more than four (4) hours.

If the unagitated bentonitic slurry is in the hole for more than four (4) hours, or if caking develops, scrape the sides to remove the filter cake before proceeding with the excavation.

The properties of the pre-mixed slurry must be checked as slurry is introduced and periodically thereafter, including a final check of a bottom sample just prior to concreting to see that the density and sand content are within the limits for proper slurry displacement during concreting. Perform control tests on the slurry to determine density, viscosity, and pH before and during shaft excavation to establish a consistent working pattern.

Let the slurry sit for 30 minutes prior to placing the reinforcing steel cage and shaft concrete, to allow the excess sand to settle out. Remove any sand and spoil that has accumulated on the bottom.

Immediately prior to placing shaft concrete, take slurry samples from the bottom and 3 meters (10 feet) from the bottom of the drilled shaft excavation using an approved slurry sampling tool. Remove any heavily contaminated slurry and spoil that has accumulated at the bottom of the shaft. Ensure the slurry is within the specification requirements immediately before concrete placement. If it is not, clean the hole and flush it with fresh slurry until subsequent tests reveal that the slurry is within the tolerances specified in these provisions.

- (1) Slurry Technical Assistance. If slurry is used, the slurry manufacturer's technical representative shall:
 - a. Provide technical assistance for the use of the slurry.
 - b. Be at the site prior to introduction of the slurry into a drilled hole.
 - c. Remain at the site during the construction and completion of a minimum of one shaft to adjust the slurry mix to the specific site conditions.
- (d) Rock Socketing. If shafts are intended to be socketed into rock per the Plans, minimum rock socket lengths shall be as shown on the Plans. The top of rock socket elevation shown on the Plans has been estimated based on test borings and survey. The actual top of rock socket may vary in the field. The top of rock sound enough to begin the socket shall be identified by the Engineer based on the existing borings and observations during shaft drilling. Weathered or highly fractured rock, as determined by the Engineer, shall not be considered sufficient for the top of rock socket. The rock socket shall begin beneath any weathered or highly fractured rock encountered, and may be lower than determined by the Engineer's interpretation of existing borings. The Engineer shall be the sole judge as to when the top of rock sound enough to begin the socket has been encountered in the field. The design rock socket length shown on the Plans shall begin at or below the depth determined by the Engineer.

- (e) Drilled Shaft Excavation Log. The Contractor shall maintain an excavation log during drilled shaft excavation. The log shall contain information such as the description and approximate top and bottom elevation of each soil or rock material encountered during shaft excavation, and any obstruction encountered. The type of tools used for the excavation shall be shown on the log. All changes in the type of tools used for excavation shall be shown on the log. The Engineer will monitor these operations and the logs will be used as a basis of measurement for payment. The Contractor shall resolve all discrepancies on the log noted by the Engineer at the end of each work day. Two copies of a legible, final log shall be furnished to the Engineer within 24 hours after a shaft excavation is completed and accepted.
- (f) Excavation Inspection. The Contractor shall provide equipment for checking the dimensions and alignment of each shaft excavation (moving drilling equipment against the sidewalls, weighted tapes, or other means approved by the Engineer). Electronic measuring equipment may be used, but is not required. The Contractor shall determine the dimensions and alignment under the direction of the Engineer. The Contractor shall measure the final shaft depth after cleaning. Unless otherwise stated in the Plans, a minimum of 50 percent of the base of each shaft shall have less than 25 mm (1 inch) of sediment. Debris at any place on the base of the shaft shall not exceed 50 mm (2 inches). The Engineer shall determine shaft cleanliness by visual inspection for dry shafts or other methods deemed appropriate by the Engineer for wet shafts.
- (g) Access Tubes for Cross-Hole Sonic Log Testing. All completed drilled shafts shall be tested with the nondestructive testing (NDT) method by the Engineer. Cross-Hole Sonic Logging (CSL) will occur after a minimum of 1 day (24 hours) of curing time has elapsed to allow the concrete to harden sufficiently. The Engineer may specify a longer minimum time if special retarders, mix designs, or other factors result in slower-setting concrete. All CSL testing shall be completed within 5 working days of concrete placement.

The Contractor shall install access tubes for CSL testing in all drilled shafts to permit access for the CSL test probes. One tube per 305 mm (1.0 foot) of shaft diameter, rounding up to the nearest whole number of tubes, (i.e., 8 tubes for a 2.4 meter (8 foot) diameter shaft) shall be installed.

The Contractor shall securely attach the access tubes to the interior of the reinforcement cage for the shaft. The access tubes shall be equally spaced around the shaft, inside the spiral or hoop reinforcement and midway between adjacent vertical reinforcement. The access tubes shall be placed 50 mm (2 inches) clear of the vertical reinforcement. If these minimums cannot be met due to

close spacing of the vertical reinforcement, then the access tubes shall be bundled with the vertical reinforcement.

The access tubes shall be installed in straight alignment and as near to parallel to the vertical axis of the reinforcement cage as possible. The tubes shall be secured, such that the tubes stay in position during reinforcement cage and concrete placement. The tubes shall extend from 150 mm (6 inches) above the shaft bottoms to a minimum of 600 mm (2 feet) above the top of the shaft. Under no circumstance shall the tubes be allowed to rest on the bottom of the drilled shaft excavation. Splice joints in the access tubes, if required to achieve full-length access tubes, shall be watertight. The Contractor shall clear the access tubes of all debris and extraneous materials prior to installing the access tubes. Care shall be taken to prevent damaging the access tubes during reinforcement cage installation and concrete placement operations.

The access tubes shall be filled with potable water prior to concrete placement. After filling with water, the top watertight caps shall be reinstalled.

Care shall be exercised in the removal of caps or plugs from the pipes after installation so as not to apply excess torque, hammering, or other stresses which could break the bond between the tubes and the concrete.

Upon completion of CSL testing and acceptance of the shaft by the Engineer, all water shall be removed from the access pipes and any other drilled holes. The pipes and holes shall then be completely filled with an approved grout having strength properties equivalent to or better than those of the drilled shaft concrete. The pipes in a particular shaft shall not be filled with grout until all testing is completed and the shaft has been accepted by the Engineer.

- (h) Reinforcing Steel. Completely assemble the reinforcing steel cage, including longitudinal bars, ties, cage stiffener bars, access tubes, centralizers, bottom supports, and other necessary appurtenances. Ties shall be installed at every intersection between vertical and horizontal (or spiral) reinforcing.

Place and center the reinforcing steel cage in the hole prior to placing concrete in the shaft. Install centralizers at the bottom and along the axial length of the steel reinforcing at sufficient spacing to maintain proper concrete cover. The longitudinal spacing shall not exceed 3 meters (10 feet). A minimum of four centralizers shall be placed at each longitudinal spacing and shall be spaced no greater than 1.2 meters (4 feet) and equally spaced around the shaft circumference. The bottom of the

cage shall be maintained at the proper distance above the base.

Check the elevation of the top of the reinforcing steel cage before and after placing the shaft concrete to ensure that no displacement of reinforcing bars has occurred. If the reinforcing steel cage is not maintained within the specified tolerances, make corrections to the satisfaction of the Engineer. Do not construct additional shafts until the procedure has been modified, to the satisfaction of the Engineer.

- (i) Placing Concrete. Concrete placement shall commence immediately after completion of excavation by the Contractor and inspection by the Engineer. Immediately prior to commencing concrete placement, the shaft excavation and the properties of the slurry (if used) shall conform to these provisions. Concrete placement shall continue in one operation to the top of the shaft, or as shown in the Plans.

Concrete for drilled shafts shall be designed and placed in such a manner that it can be pumped, or flow by gravity through a tremie to the bottom of the excavation; flow easily through the rebar cage without vibration (so that the concrete is not inadvertently mixed with drilling fluid, groundwater, soil, or rock); displace drilling slurry or water while rising in the borehole and in the annular space between the cage and the borehole wall; and not segregate or become leached of cement paste in the process. Simultaneously, the concrete shall have the appropriate strength, stiffness, and durability after it has cured.

If water is not present, the concrete shall be deposited through the center of the reinforcement cage by a method which prevents segregation of aggregates and splashing of concrete on the reinforcement cage. The concrete shall be placed such that the fall is vertical down the center of the shaft without hitting the sides, the steel reinforcing bars, or the reinforcement cage bracing.

When placing concrete underwater, the Contractor shall use a concrete pump or tremie. A tremie shall have a hopper at the top that empties into a watertight tube at least 300 mm (12 inches) in diameter. If a pump is used, a watertight tube shall be used with a minimum diameter of 100 mm (4 inches). The discharge end of the tube on the tremie or concrete pump shall include a device to seal out water while the tube is first filled with concrete. An inflatable ball will not be permitted. The device shall keep its shape and float without danger of deflation, such as a styrofoam plug.

Throughout the underwater concrete placement operation, the discharge end of the tube shall remain submerged in the concrete at least 1.5 meters (5 feet) and the tube shall be

continuous until the work is completed, resulting in a seamless, uniform shaft. If at any time during the concrete pour the pump line orifice is removed from the fluid concrete and discharges above the rising concrete level, a measurement will be made to determine the elevation and the shaft will be considered defective. The Contractor shall take appropriate and immediate action to correct the deficiency.

An example of such an action would be to recharge the pump line using a new plug, submerge the orifice below the contaminated concrete level and resume pumping, to displace the contaminated concrete. Another example would be to remove the reinforcing steel cage and concrete, complete any necessary sidewall removal directed by the Engineer, replace the reinforcing steel cage, and replace the concrete for the shaft. The Contractor shall perform the corrective action at no additional cost to the Agency.

During concrete placement, the concrete level in the drilled shaft shall be continually monitored by the Contractor and the Engineer. The difference in the concrete level between the inside of the reinforcing cage and outside of the reinforcing cage shall be no greater than 300 mm (1 foot). The reinforcing steel cage shall be installed before concrete is placed.

The Contractor's construction operations in the vicinity of a drilled shaft excavation with freshly placed concrete and curing concrete are subject to the following restrictions:

- (1) The Contractor shall not drive piling or advance drilled shaft casing in a 30 meter (100 foot) radius of a drilled shaft within 72 hours after the conclusion of placing concrete.
- (2) During the time period between six hours before concrete placement operations and seven days after completing concrete placement operations, the Contractor shall not place and advance a casing, or perform drilling within four shaft diameters of the centerline of the shaft.

This restriction may be waived if one of the following conditions is satisfied:

- a. The compressive strength of the concrete in the shaft has reached 20 MPa (3000 psi). The Contractor shall obtain and test concrete test cylinders for this early concrete strength measurement in accordance with these provisions.
- b. The Contractor has implemented a shaft vibration monitoring plan approved by the Engineer.

- (j) Shaft Construction Timing. Every effort shall be made by the Contractor in planning, coordinating, and carrying out the work to minimize the time between the start of excavation for the drilled shaft and completion of shaft concrete placement. Each step in the process of initially drilling into uncased load bearing zones, satisfactorily cleaning the shaft bottom, placing reinforcing steel, and completing concrete placement shall be coordinated to avoid delays during or between each work step. In general, the Contractor shall organize work efforts such that the time between final cleaning of the bearing zones and completion of concrete placement is less than twenty-four (24) continuous hours. No more than eight (8) continuous hours shall be permitted between the final cleaning of the excavation and the placement of concrete up to a height of 3 meters (10 feet) above the bearing zone.

For cases where eight (8) or more continuous hours elapse between final cleaning into uncased bearing zones and commencement of concrete placement, the Contractor shall clean the shaft and the reinforcing steel already placed using methods approved by the Engineer to the satisfaction of the Engineer. After cleaning, concrete placement shall be immediately commenced.

- (k) Shaft Top Preparation. The top-most concrete placed in the shaft shall be considered waste concrete and shall be either:
- (1) pushed upward and ejected completely out of the top of the casing and wasted as final concrete is placed;
 - (2) pumped upward to a level a minimum of 600 mm (24 inches) clear distance above the Plan shaft top level and allowed to cure in place for removal later; or
 - (3) placed a minimum of 600 mm (24 inches) above the Plan shaft top level via tremie, the casing dewatered prior to initial concrete set and waste concrete removed in the dry by methods approved by the Engineer.

Waste concrete shall be considered to be the top 600 mm (24 inches) of initial concrete placed, plus the height of any additional volume of waste concrete deposited in the shaft where concrete placement was halted and restarted, plus any additional amount necessary to produce full strength, non-segregated concrete at the Plan shaft top level.

Where waste concrete alternative (1) above is selected, waste concrete shall be allowed to evenly overflow the full top circumference of the casing, and may not channel or bleed off by notches or holes cut in the casing top. Any fresh concrete in the casing at a level above the Plan shaft top level after ejecting all waste concrete may be dipped or pumped out to the Plan top elevation while still

plastic by methods and equipment approved by the Engineer, or allowed to cure in place for removal later.

Where waste concrete alternative (3) above is selected, the Contractor shall submit calculations demonstrating that the concrete in the shaft at the time of dewatering provides a minimum Factor of Safety against uplift of 1.25.

Final shaft top preparation may commence only once the drilled shaft concrete obtains an average unconfined compressive strength of 17 MPa (2500 psi) or, in lieu of concrete strength testing, beginning seven (7) full days after completion of concrete placement. Final top preparation steps shall consist of:

- (1) cutting off any extra casing above the top of casing elevation;
 - (2) cutting off any cured over pour concrete to the Plan shaft top elevation by approved methods;
 - (3) dressing the final shaft top surface;
 - (4) verification by the Engineer that the exposed concrete consists of full strength concrete with a typical, non-segregated mortar and aggregate distribution;
 - (5) approved non-destructive strength testing by the Contractor where required by the Engineer to verify that concrete has full design strength; and
 - (6) removal of additional concrete below the Plan shaft top level as necessary to reach full-strength, non-segregated concrete.
- (1) Temporary Casing Removal. The Contractor shall completely remove all temporary casings, except as noted. The Contractor may leave some or all of the temporary casing in place provided all the following conditions are satisfied:
- (1) The Contractor shall submit the following information in writing to the Engineer:
 - a. A complete description of the portion of the temporary casing to remain.
 - b. The specific reason(s) for leaving the portion of the temporary casing in place.
 - c. Calculations conforming to the requirements of Section 105, using the design specification and design criteria specified in the Plans, indicating that leaving the temporary casing in place is compatible with the structure as designed in the Plans.

- (2) The Contractor shall have received the Engineer's written approval of the submitted request to leave the temporary casing in place. Any additional costs incurred as a result of leaving the temporary casing in place shall be borne by the Contractor. Additional costs may include, but are not limited to, increased shaft lengths, additional reinforcing steel, and any additional obstruction removal.
- (3) The entire length of the drilled shaft shall be in intimate contact with the adjacent surrounding soils at the completion of drilled shaft installation. If intimate contact is not achieved, as determined by the Engineer, due to temporary casing removal, temporary casing remaining in place, or for other reasons related to the means and methods of the Contractor, the annular space around the drilled shaft shall be grouted by the Contractor, to the satisfaction of the Engineer, at no expense to the Agency.

The Agency reserves the right to reject any and all proposals.

- (m) Contractor's Records. The Contractor shall keep a record, independent of that which may be kept by the Engineer, of all pertinent data relative to the installation of the drilled shaft. This record shall be available for the Engineer's inspection until the completion of the project, and a copy shall be transmitted to the Engineer within three days of the completion of each shaft. This record is to include for each shaft:

- (1) Shaft location and dates of installation.
- (2) Slurry data.
- (3) Total length of each shaft.
- (4) Plumbness of shaft.
- (5) Placement and condition of reinforcing cage.
- (6) The time, method, and duration of the concrete placement.
- (7) A log of the ambient and concrete temperatures at the time of placement.
- (8) The quantity of concrete versus depth of filled shaft.

- (n) Cross-Hole Sonic Log Testing. Cross-Hole Sonic Logging (CSL) testing and analysis on all completed drilled shafts on this project shall be conducted unless directed otherwise by the Engineer. The testing and analysis shall

be performed by an independent testing organization retained by the Agency.

The testing shall be performed after the shaft concrete has cured for a minimum of 24 hours. Additional curing time prior to testing may be required if the shaft concrete contains admixtures, such as set retarding admixture or water reducing admixture. The additional curing time prior to testing required under these circumstances shall not be grounds for additional compensation or an extension of time.

After placing the shaft concrete and before beginning CSL testing of a shaft, the Contractor shall inspect the access tubes. Each access tube that the test probe cannot pass through shall be replaced, at the Contractor's expense, with a 50 mm (2 inch) diameter hole cored through the concrete for the entire length of the shaft. Unless directed otherwise by the Engineer, cored holes shall be located approximately 150 mm (6 inches) inside the reinforcement and shall not damage the shaft reinforcement. Descriptions of inclusions and voids in cored holes shall be logged and a copy of the log shall be submitted to the Engineer. Findings from cored holes shall be preserved, identified as to location, and made available for inspection by the Engineer.

The Engineer will determine final acceptance of each shaft, based on the CSL test results and analysis for the tested shafts, and will provide a response to the Contractor within five working days after the completion of the CSL testing.

The Contractor shall not commence concrete operations in subsequent shaft excavations until the CSL tests have been accepted on the previously completed shaft and the Engineer has given approval. This requirement may be waived at the discretion of the Engineer.

- (o) Acceptance of Drilled Shafts. A comparison of the computed volume of the excavation (theoretical) with the volume of concrete placed (actual) shall be made. A plot of depth versus volume shall be computed. The Contractor shall provide cooperation and whatever assistance necessary to accurately monitor the volume of concrete placed at all times during the pour. The Engineer will determine final acceptance of each shaft and will provide a response to the Contractor within five working days after the completion of the CSL testing.

Unacceptable drilled shafts are drilled shafts that are rejected by the Engineer due to damage, failure to advance through obstructions, mislocation, misalignment, failure to install the drilled shaft to the proper bearing stratum, or the results of the CSL testing indicate defects. Rejection of a shaft based on the shaft integrity testing shall require conclusive evidence that a defect exists in the shaft which will result in inadequate or unsafe performance under service loads. If the CSL records are complex or inconclusive, the Engineer may require additional testing to confirm the location of the defect.

For all shafts determined to be unacceptable, the Contractor shall submit a remedial action plan to the Engineer for approval. If the remedial action plan requires any modifications to the dimensions of the shafts detailed in the Plans, they shall be supported by calculations and working drawings. All remedial correction procedures and designs shall be prepared by a registered professional engineer licensed in the State of Vermont and submitted to the Engineer for approval. The Contractor shall not begin repair operations until receiving the Engineer's approval of the remedial action plan.

If the Engineer determines that the concrete placed is structurally inadequate, that shaft will be rejected. The placement of concrete shall be suspended until the Contractor submits to the Engineer written changes to the methods of shaft construction needed to prevent future structurally inadequate shafts, and receives the Engineer's written approval of the submittal.

At the Engineer's direction, a core hole (standard Nx rock core) shall be drilled in any questionable quality shaft (as determined from CSL testing and analysis or by observation of the Engineer) to explore the shaft condition.

Prior to beginning coring, the Contractor shall submit to the Engineer the method and equipment used to drill and remove cores from shaft concrete. The Engineer shall issue written approval before the coring work can be started. The coring method and equipment shall provide for complete core recovery and shall minimize abrasion and erosion of the core.

If a defect is confirmed, the Contractor shall pay for all coring costs. If no defect is encountered, the Agency will pay for all coring costs as Extra Work and, if the shaft construction is on the critical path of the Contractor's schedule, compensation for the delay will be granted by an appropriate time extension.

Materials and work necessary, including engineering analysis and redesign, to effect corrections for shaft defects shall be furnished to the Engineer's satisfaction at no additional cost to the Agency.

All access tubes and cored holes shall be dewatered and filled with grout after tests are completed and the shaft is accepted. The access tubes and cored holes shall be filled using grout tubes that extend to the bottom of the tube or hole or into the grout already placed.

- xx. METHOD OF MEASUREMENT. The quantities of Special Provision (Drilled Shaft in Earth) and Special Provision (Drilled Shaft in Rock) of the size specified to be measured for payment will be the number of meters (linear feet) of drilled shaft placed in the complete and accepted work (except where measurement is made for Special Provision (Drilled Shaft Obstruction Drilling and Removal) as specified below) measured to the nearest 30 mm (0.1 foot) from the Plan top of concrete shaft elevation to the bottom of shaft. Measurement will be taken at the cross-sectional center of the shaft.

The quantity of Special Provision (Drilled Shaft Obstruction Drilling and Removal) to be measured for payment will be the number of meters (linear feet) performed in the complete and accepted work, over the depth range in which obstructions are encountered, measured to the nearest 30 mm (0.1 feet) as determined by the Engineer. No measurement for Special Provision (Drilled Shaft in Earth) will be made within the limits of Special Provision (Drilled Shaft Obstruction Drilling and Removal).

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

- xx. BASIS OF PAYMENT. The accepted quantities of Special Provision (Drilled Shaft in Earth) and Special Provision (Drilled Shaft in Rock) will be paid for at the Contract unit price per meter (linear foot). Payment will be full compensation for excavation, dewatering, temporary or permanent casing, concrete, reinforcing steel, crosshole testing access tubes, and grouting CSL tubes; and for furnishing all labor, tools, equipment, and incidentals necessary to complete the work.

No payment will be made for drilled shafts abandoned because of defects in the work or other fault of the Contractor.

The accepted quantity of Special Provision (Drilled Shaft Obstruction Drilling and Removal) will be paid for at the Contract unit price per meter (linear foot). Payment will be full compensation for performing the work of overcoming encountered obstructions and for furnishing all materials, labor, tools, equipment, and incidentals necessary to complete the work.

The accepted quantity of Special Provision (Mobilization of Drilled Shaft Equipment) (used for the construction of drilled shafts) will be paid for at the Contract lump sum price. Payment will be full compensation for mobilization, remobilization, and demobilization of drilled shaft equipment from the project including the erecting, dismantling, and all incidental tasks

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necessary to complete the work, and the furnishing of all supervision, equipment, labor, tools, and incidentals necessary to complete the work. When drilling equipment has been set up and drilling operations start, 75 percent of the Contract lump sum price will be allowed. The remaining 25 percent of the Contract lump sum price will be paid when the drilling operations are complete and the equipment has been removed from the site.

Costs associated with providing all submittals required as part of the work, and any necessary modifications thereto, will be considered incidental to the Contract items in this Section.

Payment will be made under:

<u>Pay Item</u>	<u>Pay Unit</u>
900.640 Special Provision (Drilled Shaft in Earth) (<input checked="" type="checkbox"/> M)(<input checked="" type="checkbox"/> FT)	Meter (Linear Foot)
900.640 Special Provision (Drilled Shaft in Rock) (<input checked="" type="checkbox"/> M)(<input checked="" type="checkbox"/> FT)	Meter (Linear Foot)
900.640 Special Provision (Drilled Shaft in Earth) (Test Shaft)(<input checked="" type="checkbox"/> M)(<input checked="" type="checkbox"/> FT)	Meter (Linear Foot)
900.640 Special Provision (Drilled Shaft Obstruction Drilling and Removal) (<input checked="" type="checkbox"/> M)(<input checked="" type="checkbox"/> FT)	Meter (Linear Foot)
900.645 Special Provision (Mobilization of Drilled Lump Sum Shaft Equipment)	