DRILLED SHAFTS

**From Bennington AC NH 019-1(51)

xx. DESCRIPTION. This work shall consist of mobilizing and furnishing all materials, equipment, labor, and services necessary to construct a dedicated load test shaft and 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, including test 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 or as determined based upon the test shaft results may differ from the estimated length shown in the Plans.

Drilled shaft placement may require over-water construction techniques, spoils removal, and materials delivery. When necessary, the drilled shafts shall be drilled using the wet (slurry displacement) construction method; however, pre-excavation and temporary steel casings shall be employed for constructing through the boulder layer present at the site.

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

The drilled shaft Contractor is responsible for all aspects of construction of drilled shafts including the dedicated test shaft. 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 the Contractor) visit the site where drilled shafts will be used on this project. This site visit is encouraged due to the presence of significant boulders and cobbles. In addition, the Contractor shall read the “Geotechnical Engineering Report, Roaring Branch Bridges, U.S. Route 7 Arterial – Bennington Bypass North, Bennington, Vermont” dated October, 2002 and the “Revised Drilled Shafts Design Summary Report” dated March, 2009, both available from the Agency’s Office of Contract Administration upon request.

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 encountered within 7.6 m (25 feet) of existing grade 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.

BOULDER LAYER – The boulder layer is identified on the boring logs. The boulder layer shall be pre-excavated and cased using a temporary casing.

LACUSTRINE DEPOSIT – Lacustrine deposits are identified on the boring logs and represent the bearing stratum for the drilled shafts.

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 is extracted during concreting or cut off after concrete placement.

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 these provisions and Section 501 of the Standard Specifications.

Materials shall meet the requirements of the following Subsections:

Portland Cement..701.02
Portland-Pozzolan Cement...............................701.05
Blended Silica Fume Cement.............................701.06
Fine Aggregate for Concrete............................704.01
Coarse Aggregate for Concrete..........................704.02
Chemical Admixtures....................................725.02
Air-Entraining Admixtures...........................725.02(b)
Retarding Admixtures................................725.02(c)
Water-Reducing Admixtures...........................725.02(f)
Water-Reducing and Retarding Admixtures.............725.02(g)
Water-Reducing, High Range Admixtures...............725.02(h)
Water-Reducing, High Range,
and Retarding Admixtures………........................725.02(i)
Accelerating Admixtures.............................725.02(j)
Water-Reducing and Accelerating
Admixtures..725.02(k)
Mineral Admixtures.....................................725.03
Silica Fume...725.03(b)
Ground Granulated Blast-Furnace Slag (GGBFS).......725.03(c)
Water..745.01

The proposed aggregate gradations for drilled shaft concrete may differ from those specified in Subsections 704.01 and 704.02. Maximum aggregate size is 12.5 mm (1/2”).

The portland cement concrete for drilled shafts shall consist of a homogeneous mixture of cement, fine aggregate, coarse aggregate, water, admixtures, and pozzolan (when used), proportioned and mixed in accordance with these provisions.

(b) Reinforcing Steel. Reinforcing steel shall conform to Section 507. Reinforcing steel shall have a minimum yield strength of 420 MPa (60,000 psi). Spacers 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 spacers 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 25 mm (1 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)	Time of Slurry Introduction	Time of Concreting (in hole)	Test Method
Density (kg/m^3) (lb/ft^3)	1030 to 1107 64.3 to 69.1	1030 to 1201 64.3 to 75.0	Density* Balance
Viscosity (sec./liter) (sec./quart)	30 to 47 28 to 45	30 to 47 28 to 45	Marsh Cone*
PH	8 to 11	8 to 11	pH paper or meter

* These tests shall be performed in accordance with the American Petroleum Institutes RP 13B-1 Standard Procedure for field testing Water Based Drilling Fluids.

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 as determined by the American Petroleum Institute sand content test. 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)	Time of Slurry Introduction	Time of Concreting (in hole)	Test Method
Density (kg/m^3) (lb/ft^3)	1009 to 1025 63 to 64	1009 to 1025 63 to 64	Density* Balance
Viscosity (sec./liter) (sec./quart)	48 (minimum) 45 (minimum)	48 (minimum) 45 (minimum)	Marsh Cone*
pH	7 to 11	7 to 11	pH paper or meter

* These tests shall be performed in accordance with the American Petroleum Institutes RP 13B-1 Standard Procedure 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 as determined by the American Petroleum Institute sand content test. 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 inches) 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 inch) maximum diameter source and receiver probes used for the CSL tests.

The access tubes shall be watertight 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 Subsection 745, except with a pH conforming to the slurry requirements listed above.

xx. CLASSIFICATION AND PROPORTIONING. Classification and proportioning shall meet the requirements of Subsection 501.03, with the following exceptions:

Self-consolidating concrete is a highly workable concrete that can flow through densely reinforced or complex structural elements under its own weight and adequately fill voids without segregation or excessive bleeding, and without the need for vibration.

The proposed aggregate for drilled shaft concrete may differ from those specified in Subsections 704.01 and 704.02. Maximum aggregate size is 12.5 mm (1/2 inch).

Proportioning of Self-Consolidating Concrete shall meet the following requirements:

Table A

Class	Min.*** Cem. Mat. kg/m³ (lbs./ ft³)	Max.**** Water-Cem. Mat. Ratio	Inverted slump cone Flow* mm (in.) Min	Max	Air Content(%)	28-Day** Comp. Strength MPa (psi)	56-Day** Permea-bility, Coulomb	VSI Rating	T_{50} Seconds Min	Max
SCC	362 (611)	0.44	450 (18)	610 (24)	6.5 ± 1.5	25 (3500)	2500	=/< 1	2	5

*A flow greater then 24 inches may be allowed if the Visual Stability Index (VSI) is 1 or less.
** The permeability may be tested prior to 56 days but results must still be 2500 coulombs or less.
***A 20% fly ash or 25% GGBFS replacement of total cement content is required.
**** At no time shall the maximum water exceed 172 L/m³ (38.4 gal/yd³)

If silica fume is used, the maximum shall be 24 kg/m³ (40 lbs/yd³) and shall be a direct replacement of the cement. The total batch weight of silica fume ignored shall be substituted with portland cement. Exceptions: For a one cubic yard batch, use 50 lbs of silica fume; and for a one cubic meter batch, use 34 kilograms of silica fume.

Cylinders shall be made a minimum of 70 days prior to the pre-pour meeting and submitted when the cylinders are 14 days of age. The specimens will undergo rapid chloride permeability testing at the VAOT Materials and Research AASHTO accredited laboratory at 56 days of age. If required due to time constraints, the cylinders may be tested at an age of less then 56 days, but the permeability results shall not be more then 2500 coulombs for the results to be acceptable. The test batch shall be a minimum of 3 cubic meters (4 cubic yards).

The cylinder test specimens shall be submitted with the following additional data regarding fabrication of the specimens:

(1) Compressive Strength at 4, 7, 14, 28 days of age (14 and 28 day strength results can be submitted at a later date);

(2) Test Batch Results (air content, water/cementitious ratio, flow, VSI rating, and T_{50}).

(3) J-ring test data will be supplied with test batch results. The J-ring test shall be done in accordance with ASTM C 1621 and shall be done immediately following the flow test. The results of the J-ring spread shall not be less than 50 mm (2 inches) of the flow test result.

(4) Results of tests shall indicate the flow and slump vs. time relationship for the drilled shaft concrete. The test shall be performed in a manner that approximates the condition of the concrete for the duration of the placement of the entire drilled shaft. The concrete temperature shall be taken in accordance with AASHTO T 309 and recorded for each time the flow or slump test is conducted. The tests shall be conducted for the maximum anticipated duration of concrete placement plus two hours. The flow vs. time shall be done until the flow is less than 410 mm (16 inches). Then the slump vs. time testing will begin, continuing with the time count from the flow vs. time testing. The slump shall be no less than 199 mm (4 inches) at the end of the anticipated duration. Flow/Slump testing measurements shall be taken at 30 minute intervals.

The Engineer may require a period of up to 60 calendar days from the date the aggregate is available for testing to test the material(s) and redesign the mix.

Strict adherence to the requirements of Subsection 501.07 is required when using concrete with GGBFS or fly ash. The setting time may be retarded in cool weather, or accelerated in hot weather. The Engineer, after consultation with the Agency's Structural Concrete Engineer, may require that the curing period, as designated in Table 501.17A of Subsection 501.17, be extended.

xx. BATCHING. Batching shall be performed in accordance with the requirements of Subsection 501.04, with the following exceptions:

Prior to constructing a new testing laboratory or modifying an existing laboratory, the Contractor shall submit to the Agency for approval, two sets of drawings and specifications detailing the proposed location, dimensions, and materials to be used. The details shall include the location of all testing equipment, benches, desk/file cabinet, sink, doors, windows, electrical or gas connections, and lighting, ventilating, and heating equipment.

The laboratory and all testing equipment shall be maintained in operating condition. Equipment which, during concrete operations, becomes worn or damaged to the point of being unsuitable for testing purposes, shall be replaced or repaired by the Contractor. A testing laboratory shall be required at each plant site at least one month prior to the start of batching operations, and shall remain at the site either until concreting operations on the project are completed and the concrete has been accepted, or as otherwise directed by the Materials and Research Engineer.

xx. MIXING AND DELIVERY. Mixing and delivery shall be performed in accordance with Subsection 501.05, with the following exceptions:

Transit mixer maximum load size shall be limited to 80 percent of the manufacturer's rated mixing capacity; however, legal vehicle load restrictions shall not be exceeded. The mixer shall be capable of combining the ingredients of the concrete into a thoroughly mixed and uniform mass and of discharging the concrete with a satisfactory degree of uniformity.

Agitators, when loaded, shall not exceed 80 percent of the manufacturer's rated mixing capacity or legal load restrictions, and shall be capable of maintaining the mixed concrete in a thoroughly mixed and uniform mass and of discharging the concrete with a satisfactory degree of uniformity.

The mixing speed may need to be reduced to get proper mixing action due to the nature of the high flow of the concrete.

When a transit mixer or agitator is used for transporting concrete, mixing during transport shall be at the speed designated by the manufacturer of the equipment as agitating speed.

If additional mixing water is required to maintain the specified flow and is added with the permission of the Engineer, a minimum of 20 revolutions of the transit mixer drum at mixing speed shall be required before discharge of any concrete. At no time shall the total water introduced into any mix exceed the maximum water-cementitious material ratio shown in Table A.

xx. FIELD TESTS. Field tests shall be performed accordance with Subsection 501.06, with the following exceptions:

Slump tests will not be required.

Flow tests shall be performed in accordance with ASTM C 1611, Procedure B. Do not tamp the self-consolidating concrete inside the cone. The concrete flow will be tested on the first 2 loads and at a minimum of every 15 cubic meters (20 cubic yards), including the yardage of the first two loads.

Air content tests shall be made in accordance with the pressure method in AASHTO T 152, except that the air meter shall be filled in one lift by using a scoop and dropping the concrete into the center of the pot from a distance of 150 mm (6 inches) from the top edge of the pot with no rodding. Only tap the sides of the pot if needed prior to running the test.

Test cylinders shall be made in accordance with AASHTO T 23, except the cylinders shall be filled in one lift using a scoop and dropping the concrete into the center of the mold from a distance of 150 mm (6 inches) from the top edge. The mold shall not be rodded, vibrated, or tapped on the sides unless needed. The cylinders shall be tested for compressive strength in accordance with AASHTO T 22.

T_{50} Spread Flow tests shall be performed in accordance with ASTM C 1611, Appendix X1. The T_{50} test shall be done every time the flow test is run.

Visual Stability Index (VSI) tests shall be performed in accordance with ASTM C 1611, Appendix X1 and shall be done on each completed flow test.

xx. FORMS. Forms shall meet the requirements of Subsection 501.09, with the following exceptions:

The Contractor shall design falsework and forms for full hydrostatic head pressure of the concrete. Forms shall be water tight and sufficiently rigid to prevent distortion due to the pressure of the concrete and other loads incident to the construction operations, including vibration, which should not be needed.

The specifications for forms regarding design, water tightness, filleted corners, beveled projections, bracing, alignment, removal, reuse, and oiling also apply to metal forms.

xx. PLACING CONCRETE. Placing concrete shall meet the requirements of Subsection 501.10, with the following exceptions:

Self-consolidating concrete shall not be deposited in the forms more than 6 meters (20 feet) horizontally from its final position.

As the final elevation is reached for the pour, the concrete will need to be placed closer to its final resting place in order to minimize the amount of manpower needed to move the concrete. Dropping of unconfined self-consolidating concrete more than 1.5 meters (5 feet) will not be permitted.

Unless otherwise specified, self-consolidating concrete shall not be consolidated with mechanical vibrators. If the Engineer requests the use of a vibrator, it shall be of an approved type and design, operating within the concrete. It shall be used as little as possible to avoid segregation of the concrete.

xx. PREQUALIFICATION. The drilled shaft 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 over-water installations.

(b) The foreman for this work having supervised the successful installation of drilled shafts on a minimum of two projects in the last two years, and;

(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.

(d) The Contractor shall submit the proof and details for the independent testing organization retained for the Osterberg Cell Load testing as follows:

(1) Three projects in the past five years where the testing firm performing the work has successfully performed Osterberg Cell Load Testing of drilled shafts with similar diameter and length as required for this project, and a minimum of one project requiring similar over-water installations.

(2) The foreman for this work having supervised the successful Osterberg Cell Load Testing of drilled shafts on a minimum of two projects in the last two years, and;

(3) The test operators having had a minimum of one year of experience performing Osterberg Cell Load Testing on 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.

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 15 working days. The Contractor or subcontractor will not be permitted to install drilled shafts without this approval.

Prequalification requirements shall be strictly enforced. Approvals are subject to satisfactory field performance.

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 referred to as “plan”) 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, including dedicated test shaft. 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) Details and methods describing erosion control measures in conformance with the project’s Erosion and Protection measures as approved by the Engineer.

(2) Details and method describing how the Contractor will keep the hole for the drilled shaft open.

(3) Details of 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, sampling equipment, tremies or concrete pumps, and casing, including casing dimensions, material and splice details, etc. Provide a detailed description of procedures for temporary and permanent casing installation removal as applicable.

(4) 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 and removal of spoils.

(5) Shaft excavation methods, and verification methods of final shaft dimensions and verticality. Include details of proposed corrective measures to be implemented as necessary.

(6) If slurry is to be used, a slurry management plan indicating the method proposed to mix, circulate, and de-sand slurry, and method of monitoring and continuously maintaining slurry level in drilled shafts. Include methods of slurry disposal in the submittal and types and frequencies of tests to be performed. Include temperature correction tables for density and viscosity for the slurry used on the project.

(7) Details of steel reinforcement lifting, splicing, insertion, and securing, including support and centralization methods.

(8) 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.

(9) Approved concrete mix design in accordance with MATERIALS of this Section.

(10) 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.

(11) 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.

(12) Description of the type of feet to be used to support the reinforcing steel cage in the drilled shaft.

(13) Emergency construction joint procedure, to be used when concrete placement for the drilled shaft is unexpectedly interrupted.

(14) 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.

(15) Method for reinsertion of a tremie pipe, if required.

(16) Details of equipment and procedures for obstruction removal, including the types of chisels and grabs.

(17) 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.

(18) Details of procedures and equipment for the drilled shafts.

The Contractor shall propose a location for the test shaft. The proposed location shall be submitted to the Engineer for review. The Engineer will evaluate the proposal and either accept or reject the location.

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) Dedicated Test 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 dedicated test shaft. The purpose of the meeting shall 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, 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. All parties shall be notified a minimum of 7 days in advance of the meeting date.

A follow-up meeting shall be held with the same attendees from the Contractor, after test shaft results are obtained and prior to production shaft construction.

(c) Production Shaft Installation Sequencing and Scheduling.

(1) Production shafts may commence only after successful completion and acceptance of the dedicated test shaft(s), and Osterberg Cell load testing report.

(2) 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, accepted by the Engineer, and reinforcing steel placed and accepted.

(3) 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.

(4) Vibration or excessive wheel loads shall 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.

(d) 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.

(e) 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.

(f) 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 install 4 access tubes in the 1.22 meter (4 feet) diameter load test shaft.

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 (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 as soon as possible after concrete placement, but not later than 4 hours after 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.

(g) 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 (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 eight centralizers shall be placed at each longitudinal spacing and shall be equally spaced around the shaft circumference. Place approved cylindrical feet (bottom supports) at the bottom of the cage to ensure that the bottom of the cage is 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.

(h) 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, or 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.

When placing concrete in the dry, only the top 1.5 meters (5 feet) of concrete shall be vibrated. Vibration of the top 1.5 meter (5 feet) of concrete does not affect the maximum slump allowed for the concrete class specified.

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 operation 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 (9.8 meters or 32 feet) 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.

(i) <u>Shaft Construction Timing</u>. 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.

(j) <u>Shaft Top Preparation</u>. 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.

(k) 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 of the following conditions are satisfied:

(1) The Contractor shall submit the following information in writing to the Engineer:

a. The Contractor shall completely describe the portion of the temporary casing to remain.

b. The Contractor shall specify the reason(s) for leaving the portion of the temporary casing in place.

c. The Contractor shall submit structural calculations, using the design specifications and design criteria specified in the Contract Documents, 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.

(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 additional cost to the Agency.

(l) 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.

(m) 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.

(n) Osterberg Cell Load Testing. An independent testing organization retained by the Contractor shall perform Osterberg Cell (O-Cell) load tests on a 1.22 m (4 foot) diameter dedicated test shaft. The purpose of the load test is to determine the end bearing capacity and the friction/adhesion resistance of the Lacustrine deposit. The load test data will provide the opportunity to confirm the shaft design assumptions and installation methods. The final end bearing and friction/adhesion design values will be reviewed by the Engineer based on the load and deformation data obtained in the tests. Adjustment of shaft lengths may be made by the Engineer on the basis of O-Cell test results. The Engineer shall inform the Contractor within 5 days of the load test if any adjustment of the shaft length is required.

An independent testing organization retained by the Contractor shall furnish all labor necessary for conducting O-Cell load tests and reporting the results. The Contractor shall supply all material and labor as hereinafter specified and including prior to, during, and after the load test. The test shaft shall be constructed in the same manner as production shafts in accordance with the approved testing plan and shop drawings, and the requirements of these provisions.

The Contractor, in cooperation with the O-Cell supplier, and the independent testing organization retained by the Contractor, shall supply and supervise the mobilization, assembly, and operation of the O-Cell load test equipment. The O-Cell supplier shall supply and install the required instrumentation in the shaft. The O-Cell supplier shall acquire the test data during testing and compile the O-Cell data into a report. The report shall be presented to the Engineer.

(1) Osterberg Load Cell. The Contractor shall furnish two (2) or more O-Cells for the multi-level testing as required for the load test, as indicated on the Plans. Testing shall be performed in a two-stage loading sequence that will allow end bearing and side friction capacities to be measured in one test shaft.

Provide an O-Cell that is flat, hydraulically expanded, and capable of developing the required loads upward and downward when embedded in the test shaft as indicated on the Plans, with a vertical displacement capacity of 150 mm (6 inches). The applied load of the cell shall be accurate to within 1 percent, shall expand uniformly, and shall be capable of being installed and operated as shown and specified. Provide at the bottom and top of each cell a combination of steel plates that will serve to uniformly distribute the applied load to the bearing stratum.

The O-Cell(s) to be provided at each level for the multi-level load testing should have a test capacity each of at least 16 MN (3600 kips) in each direction. The O-Cell shall be equipped with all necessary hydraulic lines, fittings, pressure source, pressure gage, strain gages, and telltale devices.

(2) Vibrating Wire Strain Gages (VWSG). Provide new, expendable vibrating wire strain gages, Geokon Model-4911, or acceptable equivalent, which are to be cast into the drilled test shaft at locations indicated on the Plans and shop drawings. Each strain gage shall have a minimum range of 2,500 microstrain and be capable of measuring changes in strain of 1 microstrain. Instrumentation shall be documented by previous similar field experience as being able to remain calibrated and operational throughout the load test. VWSGs shall be capable of measuring temperature.

Provide one strain gage along the shaft in the soil above the upper O-Cell. The strain gage shall be installed 1.5 meters (5 feet) below the tip/bottom of the temporary casing level.

Provide two levels of strain gages (2 per level) above the lower O-Cell evenly spaced between the two Osterberg cells.

(3) Telltales. Provide two (2) 6 mm (¼ inch) diameter flush-coupled stainless steel telltale rods to each O-Cell. Telltales shall be installed in accordance with shop drawings to be provided by Contractor. The telltale rod sections shall be straight, corrosion

free, and undamaged. The base of the bottom telltale rod shall be machined flat.

The telltale sleeve pipe shall consist of 13 mm (½ inch) diameter Schedule 80 black steel pipe with external threaded couplings and shall be connected to a rebar anchor below the sleeve. The rebar anchor shall consist of a 300 mm (12 inch) long, 19 mm (#6) rebar, the top of which shall be machined flat and perpendicular to the axis of the rebar to provide repeatable contact with telltale rod.

(4) Dial Gages. Provide dial gages consisting of dial indicators for use in measuring deflection at the top of the drilled shaft during load testing. Dial gage indicators shall have a range of 100 mm (4 inches) and be graduated to .025 mm (0.0001 inch) divisions. Smooth-bearing surfaces perpendicular to the direction of gage-stem travel shall be provided for three gage stems. Provisions shall be made for free movement of the dial gage should it become necessary to reset the micrometer dials during load testing.

The Contractor shall supply all equipment and materials required to install the O-Cell and remove the load test apparatus as required. The Contractor shall also supply the materials and construct a stable reference beam system for monitoring movements of the shaft during testing, supported at a minimum distance of 3 diameters from the center of the shaft to prevent disturbance of the reference system.

(5) Pre-Installation Acceptance Tests. When instruments are received at the site, the Contractor and the testing firm, through the Engineer, shall perform pre-installation acceptance tests submitted by the Contractor to ensure that the instruments and readout units are functioning correctly prior to installation.

During pre-installation acceptance testing of each instrument, the Contractor and the testing firm, through the Engineer, shall complete a test record sheet.

Any instrument that fails the specified pre-installation acceptance test shall be repaired or shall be replaced by an identical instrument at no cost to the Agency.

(6) Installation Procedures - General. The Contractor shall construct the dedicated drilled test shaft as shown on the Plans, or as directed by the Engineer, using approved procedures and details similar to those to be used for the production shafts.

Remove loose soil and debris prior to placement of the O-Cell. Use airlift type recirculation equipment and other equipment as necessary. Conduct excavation bottom tests in each drilled test shaft by sounding with the airlift pipe, heavily weighted tape, and by other accepted means to determine that no loose material is present on the hard undisturbed surface. Conduct excavation bottom test no more than 2 hours prior to placement of the O-Cell. Clean bottom until acceptable to the Resident Engineer.

The O-Cells, hydraulic supply lines, and other attachments shall be assembled and made ready for installation under the direction of the testing firm and the Engineer, in a suitable area adjacent to the test shaft, to be provided by the Contractor.

When the test shaft excavation has been constructed, inspected, and accepted by the Engineer, lower the O-Cells and instrumentation CSL tubes and reinforcing steel cage as shown on the Plans, into the excavation until it is in firm contact with the bottom. Support entire assembly while picking up and lowering into excavation to prevent bending or damage of any components. A seating layer consisting of a minimum 300 mm (1 foot) thick layer of cement grout shall be placed at the bottom of the excavation to provide a level base and reaction for the O-cell assembly. The grout cement for the seating layer can be placed through the test shaft tremie tube or placed prior to the installation of the O-cell assembly. The O-cell assembly shall be placed while the seating layer is fluid. The O-cell shall be firmly seated in the base grout cement.

The Contractor shall use care in handling the steel cage/test equipment assembly so as not to damage the instrumentation during installation. The Contractor shall limit the deflection of the steel cage between pick points while lifting the frame from the horizontal position to vertical. The maximum spacing between pick points shall be 6.1 m (20 feet). The Contractor shall provide support bracing and strong backs to maintain the deflection within the specified tolerance.

In lieu of cement grout, the Contractor may submit alternate load cell seating methods with their required submittals.

After seating the O-Cell assembly, the drilled shaft shall be concreted in a continuous (without interruption) manner similar to that specified for production shafts. A minimum of six (6) concrete compression test cylinders shall be molded from the concrete used in the test shaft. A minimum of one of these cylinders shall be tested prior to the load test and a minimum of two cylinders shall be tested on the day of the load test.

After the completion of the load test and acceptance of the preliminary load test report, and at the direction of the Engineer, the Contractor shall remove any equipment, material, and waste.

(7) Post-Installation Acceptance Tests. After the installation of the O-Cell assembly, the Contractor and the testing firm, through the Engineer, shall perform post-installation acceptance tests submitted by the Contractor.

Any instrument that fails the specified post-installation acceptance test shall require repair or replacement by an identical instrument at no cost to the Agency. The Engineer shall determine whether or not replacement is required.

If during the period required to perform the load test, the test apparatus shows any signs of negative effects due to construction activities, such activities shall cease immediately.

(8) O-Cell Load Test Sequencing.

a. General. The multi-level O-Cell load testing shall be performed in two consecutive stages. Stage 1 includes the lower level O-Cell load testing of the drilled shaft bearing capacity. Stage 2 includes the upper level O-Cell load testing of the soil side shear capacity.

b. Stage 1 Load Testing. Perform load testing of lower O-cell for end bearing capacity using the shaft length as a reaction. Load shaft to ultimate/failure conditions in end bearing.

c. Stage 2 Load Testing. Perform load testing of side shear using the entire lower portion of the shaft as a reaction. Load shaft to ultimate/failure conditions in side shear.

(9) O-Cell Load Testing. The load testing shall be performed in general compliance with ASTM D 1143 (Quick Test Method) and shop drawings in the presence of the Engineer. Initially, the loads shall be applied in increments equaling 5% of the anticipated design capacity (5340 kN) of the test shaft. The magnitude of the load increments may be increased or decreased depending upon the actual test shaft capacity.

Loads shall be applied at the prescribed intervals, in accordance with ASTM D 1143, until the failure of the shaft is reached in side shear and/or end bearing, or until the maximum capacity or maximum stroke of the O-Cell is reached, unless otherwise directed by the Engineer. The failure criterion is defined as gross movement that exceeds five percent of the diameter of the test shaft (61 mm (2.4 inches)).

At each load increment, or decrement, movement indicators shall be read at 1.0, 2.0, 4.0, and 8.0 minute intervals while the load is held constant. During unloading cycles, the load decrement shall be such that a minimum of four data points are acquired for the load versus movement curve. Additional cycles of loading and unloading using similar procedures may be required by the Engineer following the completion of the initial test cycle.

Direct movement indicator measurements shall be made of the following: downward shaft end-bearing movement (minimum of two indicators required), upward top-of-shaft movement (minimum of two indicators required), shaft compression (minimum of two indicators required).

Dial gages, digital gages, or Linear Vibrating Wire Displacement Transducers (LVWDT) used to measure end bearing and side shear movement shall have a minimum travel of 200 mm (8 inches) and be capable of being read to the nearest .025 mm (0.0001 inch) division. End bearing movement may be alternately monitored using LVWDT’s capable of measuring the expansion of the O-Cell, up to 150 mm (6 inches). Dial gages, digital gages, or LVWDT’s used to measure the shaft compression shall have a minimum travel of 25 mm (1 inch) and be capable of being read to the nearest .025 mm (0.0001 inch) division.

The reference beam selected shall have a minimum length equal to six times the shaft diameter and shall be monitored for movement during load testing using a surveyor’s level.

Obtain Engineer's acceptance of performance of each test prior to disassembling test equipment.

After the completion of the load test and acceptance of the preliminary load test report, and at the direction of the Engineer, remove equipment, material, and waste that are not to be a part of the finished structure.

If the Engineer does not accept the loading test, the Contractor shall not be compensated for the unsatisfactory load testing.

(10) O-Cell Load Testing Report. A report providing all data readings and plots of the readings, as well as a

determination of the friction/adhesion and end bearing of the soils, shall be submitted to the Engineer for review.

Three copies of an initial data report containing the load-movement curves and test data shall be provided to the Engineer within 48 hours (2 working days) of the completion of load testing, to allow evaluation of the test results.

A final report (three copies) on the load testing shall be submitted to the Engineer within five (5) working days after completion of the load testing. As a minimum, the report shall include the following:

a. As-installed location of the test shaft.

b. Logs of test borings conducted at the test shaft location.

c. Installation records of test shaft showing locations of all instrumentation.

d. Summary of the load test procedure and data collected during load testing.

e. Analysis of unit side adhesion and unit end-bearing pressure in the test shaft.

f. Summary of the failure mechanism of the test shaft.

g. Plots of axial load versus displacement at the base of the shaft, and axial load versus displacement and/or strain along the test shaft.

(11) The testing and analysis of the drilled shafts shall be performed by an independent testing organization retained by the Contractor. The Contractor shall provide information required under Section 114 PREQUALIFICATION to the Engineer for review, evaluation, and approval prior to submitting detailed information as required under <u>SUBMITTALS AND PRECONSTRUCTION REQUIREMENTS</u>

(o) <u>Acceptance of Drilled Shafts</u>. 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, based on the crosshole sonic log test results and analysis for the test shafts, 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 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 corehole (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. 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 quantity of Special Provision (Drilled Shaft in Earth) 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 center of the shaft.

The quantity of Special Provision (Drilled Shaft Obstruction Drilling and Removal) of the size specified 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 in the complete and accepted work.

xx. BASIS OF PAYMENT. The accepted quantity of Special Provision (Drilled Shaft in Earth) 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, crosshole testing access tubes, grouting CSL tubes, and for furnishing all labor, tools, equipment, and incidentals necessary to complete the work.

Reinforcing steel, including stainless steel reinforcing, shall be paid for under the appropriate pay items in the Contract Plans.

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

Payment will be made under:

	Pay Item	Pay Unit
900.640	Special Provision (Drilled Shaft in Earth) (X M)(X FT)	Meter (Linear Foot)
900.640	Special Provision (Drilled Shaft in Earth) (Test Shaft)(X M)(X FT)	Meter (Linear Foot)
900.640	Special Provision (Drilled Shaft Obstruction Drilling and Removal) (X M)(X FT)	Meter (Linear Foot)
900.645	Special Provision (Mobilization of Drilled Shaft Equipment)	Lump Sum