ITEM #0702048 - OBSTRUCTIONS
ITEM #0702062 - FURNISHING DRILLED SHAFT DRILLING EQUIPMENT
ITEM #0702064 - DRILLED SHAFT (10.0FT)
ITEM #0702066 - TRIAL DRILLED SHAFT (10.0FT)
ITEM #0702774 - ACCESS TUBES
ITEM #0702861 - DRILLED SHAFT ROCK EXCAVATION (9.5FT)
ITEM #0702881 - DRILLED SHAFT EARTH EXCAVATION (10.0FT)
ITEM #0702923 - PERMANENT CASING (10.0FT)

Description: This work shall consist of all labor, materials, equipment and services necessary to perform all operations to complete the drilled shaft installation in accordance with this specification, the special provisions and with the details and dimensions shown on the plans. Drilled shafts shall consist of reinforced or unreinforced concrete.

Related work that may be specified elsewhere:

Integrity Testing – Cross Hole
Integrity Testing - Reflection
Osterberg Cell Load Testing of Drilled Shaft
Stanamic Axial Load Testing of Drilled Shaft

Materials: Materials for Drilled Shafts shall consist of the following:

1-Portland Cement Concrete: Concrete used in the construction of the shaft shall conform to the plans, Article M.03.01 of the Standard Specifications, and as follows:

(a) The concrete shall have a minimum initial slump of 8 inches.

(b) The concrete mix shall maintain a slump of 4 inches or greater for a minimum 3 hours beyond the expected time for placement of concrete and removal of temporary casing (if used), as demonstrated by trial mix and slump loss tests. The trial mix and slump loss tests shall be conducted using concrete and maximum temperatures appropriate for site conditions.

(c) Admixtures such as water reducers, plasticizers, and retarders shall not be used in the concrete mix unless permitted in the contract documents or by the Engineer. All admixtures, when approved for use, shall be adjusted for the conditions encountered on the job so as to conform to the slump loss requirements within this specification and not to adversely affect the timing of, taking of and/or interpretation of any Nondestructive Testing that may be called out for in the contract.

(d) Coarse aggregate shall conform to Article M.01.01 of the Standard Specifications, No. 8 Gradation.

2-Reinforcing Steel: Reinforcing steel used in construction of the shaft shall conform to the plans and Article M.06.01 of the Standard Specifications.

3- Access Tubes: Access tubes for crosshole acoustic logging shall consist of Schedule 40 steel pipe conforming to ASTM A 53, Grade A or B, Type E, F, or S. The inside diameter shall be at least 1.5 inches. All access tubes shall have a round, regular inside surface free of defects and obstructions, including all pipe joints, in order to permit the free, unobstructed passage of probes to the bottoms of the tubes. The access tubes shall be watertight, free from corrosion and free of deleterious material on the outside that can prevent bonding with the concrete. All access tubes shall be fitted with watertight caps on the bottom and top.

4-Grout: Grout used for filling Access Tubes shall conform to the requirements of Article M.03.01-12 of the Standard Specifications. The grout shall have strength properties equivalent to or better than those of the drilled shaft concrete.

5-Permanent Casing: Casing shall conform to Article M.06.02 of the Standard Specifications. Casings shall be steel, smooth, clean, watertight, and of ample strength to withstand both handling and installation and the pressure of both concrete and the surrounding earth materials. The outside diameter of casing shall not be less than the specified diameter of shaft and the outside diameter of any excavation made below the casing shall not be less than the specified diameter of the shaft.

Construction Methods:

1-Qualifications of Drilled Shaft Contractor and Submittals: The Contractor performing the work described in this specification shall have installed drilled shafts of both diameter and length similar to those shown on the plans for a minimum of three (3) years prior to the bid date for this project.

The Contractor shall submit both a list containing at least three (3) projects completed in the last three (3) years on which the Contractor has installed drilled shafts of a diameter and length similar to those shown on the plans. The list of projects shall contain names and phone numbers of owner's representatives who can verify the Contractors' participation on those projects.

As early as possible and no later than 30 days prior to constructing drilled shafts, the Contractor shall submit an installation plan for review by the Engineer. This plan shall provide information on the following:

(a) A list identifying the on-site supervisor(s) and drill operator(s) for approval by the Engineer. The on-site supervisor(s) shall have a minimum two years experience in supervising the construction of drilled shafts of a diameter and length similar to those shown on the plans. The drill operator(s) shall have a minimum one-year experience in drilling for the construction of drilled shafts of a diameter and length similar to those shown on the plans. The list shall contain a summary of each individual’s experience. Should the Contractor elect to change personnel during construction of the shaft, the same approval process will

need to be completed for the new personnel prior to them starting work on the project. The Contractor shall not be compensated for any delays resulting from their changing of personnel.

(b) List of proposed equipment to be used, including cranes, drills, augers, bailing buckets, final cleaning equipment, desanding equipment, slurry pumps, core sampling equipment, tremies or concrete pumps, casing. etc.

(c) Details of overall construction operation sequence and the sequence of shaft construction in bents or groups.

(d) Details of shaft excavation methods.

(e) When the use of slurry is anticipated, details of the mix design and its suitability for the subsurface conditions at the construction site, mixing and storage methods, maintenance methods, and disposal procedures.

(f) Details of methods to clean the shaft excavation.

(g) Details of reinforcement placement, including support and centralization methods.

(h) Details of concrete mix design and test results of both a trial mix and a slump loss test. The tests shall be conducted by an approved testing laboratory using approved methods to demonstrate that the concrete meets slump loss requirements.

(i) Details of concrete placement, including proposed operational procedures for free fall, tremie or pumping methods, proposed concreting log form and computations for time duration of shaft pour estimates.

(j) Details of casing installation and removal methods.

(k) Details of methods for removal of obstructions. Obstructions the Contractor shall provide details of methods for removal include, but are not necessarily be limited to, boulders, concrete, riprap, steel, timber, etc.

The Engineer will evaluate the drilled shaft installation plan for conformance with the plans, specifications and special provisions and will then notify the Contractor of any additional information required and/or changes necessary to meet the contract requirements. All procedural approvals given by the Engineer shall be subject to trial in the field and shall not relieve the Contractor of the responsibility to satisfactorily complete the work as detailed in the plans and specifications. The Contractor shall not commence construction of the drilled shafts until the Engineer has approved the installation plans.

If integrity and/or load testing of the drilled shafts are called for, this submittal shall be

developed in coordination with and submitted concurrently working drawing submittals as required in the testing specifications.

All submittals shall comply with the working drawing submittal requirements as outlined in Article 1.05.02 of the Form 816.

2-Trial Drilled Shaft Installation and Load Testing: If called for in the contract, the Contractor shall demonstrate the adequacy of his methods, techniques and equipment by successfully constructing a trial drilled shaft in accordance with this specification's requirements. This trial drilled shaft shall be positioned away from production shafts in the location shown on the plans or as directed by the Engineer. The trial shaft shall be drilled to the maximum depth shown in the plans. Failure by the Contractor to demonstrate to the Engineer the adequacy of methods and equipment shall be reason for the Engineer to require alterations in equipment and/or method by the Contractor to eliminate unsatisfactory results. Any additional trial drilled shaft required to demonstrate the adequacy of altered methods or construction equipment shall be at the Contractor's expense. Once approval has been given to construct production shafts, no changes will be permitted in the materials, methods and/or equipment used to construct the satisfactory trial drilled shaft without written approval of the Engineer. .

Unless otherwise shown in the contract documents, the trial drilled shaft will be filled with concrete in the same manner that production shafts will be constructed. The trial drilled shaft shall be cut off two feet below finished grade and left in place. The disturbed areas at the sites of the trial drilled shaft shall be restored as nearly as practical to their original condition.

Should the plans call for load testing of the trial drilled shaft, all necessary loading apparatus, instrumentation, etc. required for performing the load test will be specified and paid for under a separate item.

Commentary: The special provision should also include some form of the following statement; "All trial drilled shaft(s) and load test(s) shall be completed and accepted by the Engineer prior to construction of any production drilled shafts." This statement may require modification on a job by job basis depending on the need for one or more trial shafts and/or test to be performed on drilled shafts of different dimensions, loads, construction techniques, geologic bond zones, etc.

3-Protection of Existing Structures: The Contractor shall control his operations to prevent damage to existing structures and utilities in accordance to Articles 1.07.09 and 1.07.10 of the Standard Specifications. Preventive measures shall include, but are not limited to, selecting construction methods and procedures that will prevent caving of the shaft excavation and monitoring and controlling the vibrations from construction activities such as the driving of casing or sheeting, drilling of the shaft, or from blasting, if permitted.

If monitoring is called for in the plans, a preconstruction survey of existing facilities should be performed to establish baseline data, including ambient vibration levels and existing structural defects. In general, monumented survey points should be established on structures which are located within a distance of either ten shaft diameters or the estimated shaft depth, whichever is greater. These points should be monitored by the Contractor for vertical and lateral movement in an approved manner to the accuracy determined by the Engineer.

When deformations exceed the predetermined amount included in the plans, the Contractor shall immediately stop work and, if directed by the Engineer, backfill the excavated hole. The Contractor shall be responsible for selecting and using equipment and procedures that keep deformations of existing structures within specified levels.

When vibrations are to be monitored, the Contractor should be directed to engage the services of a professional vibrations consultant to monitor and record vibration levels during drilled shaft construction. In general, vibration monitoring equipment should be capable of detecting velocities of 0.1 inch per second or less. When vibration levels exceed established tolerable levels the Contractor should immediately stop work and take whatever measures are necessary to reduce vibration levels below tolerable levels.

4-Construction Sequence: Excavation to footing elevation shall be completed before shaft construction begins unless otherwise noted in the contract documents or approved by the Engineer. Any disturbance at or below the footing area caused by shaft installation shall be repaired by the Contractor prior to the footing pour. .

When drilled shafts are to be installed in conjunction with embankment placement, the Contractor shall construct drilled shafts after the placement of fills unless shown otherwise in the contract documents or approved by the Engineer.

Drilled shafts, constructed prior to the completion of the fills, shall not be capped until the fills have been placed as near to final grade as possible, leaving only the necessary workroom for construction of the caps.

5-Exploration Test Borings: As early as possible, the Contractor shall take soil samples or rock cores where shown on the plans or as directed by the Engineer to determine the character of the material directly below the completed shaft excavation. The soil samples shall be extracted with a split spoon sampler or undisturbed sample tube. The rock cores shall be cut with an approved triple tube core barrel to a minimum of 10 feet below the bottom of the drilled shaft excavation before the excavation is made. The Engineer may require the depth of coring to be extended up to a total depth of 20 feet. Rock core and standard penetration test samples shall be measured, visually identified and described on the Contractor's log. The samples shall be placed in suitable containers, identified by shaft location, elevation, and project number and delivered with the Contractor's field log to the Engineer. The samples and field log shall be delivered to the Engineer within 24 hours after each boring exploration is complete. The Engineer shall inspect the samples and log to determine the final depth of required excavation based on his evaluation of the material's suitability. The Contractor shall not start shaft drilling or construction of the shafts until the Engineer has determined the final depth of required excavation. Two copies of the Contractor's final typed log shall be furnished to the Engineer within 7 calendar days upon completion of the borings. The logs should contain specific information about the drilling equipment and tools used and rate of hole advancement, as well as, descriptions of soil, rock, obstructions, and water encountered. The Contractor shall supply a suitable, secure site for storage of all soil and rock core samples on the project site. At no time shall the soil or rock core samples be taken off the project site without approval from the Engineer.

6-General Methods and Equipment: The Contractor shall perform the excavations required for shafts through whatever materials are encountered, to the dimensions and elevations shown in the plans or otherwise required by the specifications and special provisions. The Contractor's methods and equipment shall be suitable for the intended purpose and materials encountered. The permanent casing method shall be used only at locations shown on the plans or when authorized by the Engineer in writing. Blasting shall only be permitted if specifically stated on the plans or authorized in writing by the Engineer.

7-Uncased Construction Method: This method consists of using water or slurry (mineral or polymer) to maintain stability of the borehole perimeter while advancing the excavation to final depth, placing the reinforcing cage, and concreting the shaft. Where drilled shafts are located in open water areas, exterior casings shall be extended from above the water elevation into the ground to protect the shaft concrete from water action during placement and curing of the concrete. The exterior casing shall be installed in a manner that will produce a positive seal at the bottom of the casing so that no piping of water or other materials occurs into or from the shaft excavation.

8-Casing Construction Method: The casing method may be used either when shown on the plans or at sites where the uncased construction methods are inadequate to prevent hole caving or excessive deformation of the hole. In this method the casing may be either placed in a predrilled hole or advanced through the ground by twisting, driving or vibration before being cleaned out.

9-Excavation and Drilling Equipment: The excavation and drilling equipment shall have adequate capacity, including power, torque and down thrust to excavate a hole of both the maximum diameter and to a depth of 20 percent beyond the depths shown on the plans.

The excavation and overreaming tools shall be of adequate design, size and strength to perform the work shown in the plans or described herein. When the material encountered cannot be drilled using conventional earth augers with soil or rock teeth, drill buckets, grooving tools, and/or underreaming tools, the Contractor shall provide special drilling equipment, including but not limited to: rock core barrels, rock tools, air tools, blasting materials, and other equipment as necessary to construct the shaft excavation to the size and depth required. Approval of the Engineer is required before excavation by blasting is permitted.

10-Excavation: Shaft excavations shall be made at locations and to the top of shaft elevations, estimated bottom of shaft elevations, shaft geometry and dimensions shown in the contract documents. The Contractor shall extend drilled shaft tip (base) elevations when the Engineer determines that the material encountered during excavation is unsuitable and/or differs from that anticipated in the design of the drilled shaft.

The Contractor shall maintain a construction method log during shaft excavation. The log shall contain information such as: the description and approximate top and bottom elevation of each soil or rock material encountered, seepage or ground water, and remarks, including a description of the tools and drill rigs used and any changes necessitated by changing ground conditions.

Excavated materials that are removed from shaft excavations shall be disposed of by the Contractor in accordance with the applicable specifications for disposal of excavated materials and

in conformance with Article 1.10 of the Standard Specifications.

The Contractor shall not permit workers to enter the shaft excavation for any reason unless: both a suitable casing has been installed and the water level has been lowered and stabilized below the level to be occupied, and adequate safety equipment and procedures have been provided to workers entering the excavation.

11-Drilled Shaft Earth Excavation: Drilled shaft earth excavation is excavation accomplished with conventional tools such as augers, and drilling buckets attached to drilling equipment of the size, power, torque, and down thrust (crowd) as proposed by the Contractor in their construction procedure that has been approved for use by the Engineer and/or successful construction of a trial drilled shaft. Earth excavation may included, but not necessarily be limited to, clay, silt, sand, gravel, cobbles, boulders, weathered rock, and miscellaneous fill.

12-Drilled Shaft Rock Excavation: Drilled shaft rock excavation is excavation of competent rock, accomplished with conventional rock drilling tools, such as core barrels, attached to drilling equipment of the size, power, torque, and down thrust (crowd) as proposed by the Contractor in their construction procedure that has been approved for use by the Engineer and/or successful construction of a trial drilled shaft. Top of competent rock is as defined on the contract drawings.

13-Obstructions: When obstructions are encountered, the Contractor shall notify the Engineer immediately. Obstructions are defined as a impenetrable objects that a) cannot be removed or excavated using conventional augers fitted with soil or rock teeth, underreaming tools, and/or drilling buckets, and b) cause a significant decrease in the rate of excavation advancement, relative to the rate of advancement for the rest of the shaft excavation within the particular strata that the obstruction is located in, if removed using the techniques and equipment used successfully to excavate the shaft.

The Engineer will be the sole judge of the significance of any reduced rate of shaft advancement and the classification of obstruction excavation. The Engineer shall be present to evaluate the occurrence of obstructions, to authorize, and to approve the designation of such. Sloping bedrock and/or higher than anticipated bedrock shall not be considered obstruction excavation. Shallow obstructions are those obstructions located within 5 feet of the top level of the shaft. Shallow obstructions at shaft locations shall be removed at the expense of the Contractor.

The Contractor shall remove all subsurface obstructions at drilled shaft locations. Such obstructions may include man-made materials such as old concrete foundations and natural materials such as boulders. Such special procedures/tools may include but are not limited to: chisels, boulder breakers, core barrels, down the hole hammers, air tools, hand excavation, temporary casing, and increasing the hole diameter. Blasting shall not be permitted unless specifically approved in writing by the Engineer.

14-Lost Tools: Drilling tools that are lost in the excavation shall not be considered obstructions and shall be promptly removed by the Contractor without compensation. All costs due to lost tool removal shall be borne by the Contractor including, but not limited to, costs associated with the repair of hole degradation due to removal operations or an excessive time that the hole remains open.

15-Casing: Casings shall be steel, smooth, clean, watertight, and of ample strength to withstand both handling and installation and the pressure of both concrete and the surrounding earth materials. The outside diameter of casing shall not be less than the specified diameter of shaft, and the outside diameter of any excavation made below the casing shall not be less than the specified diameter of the shaft. No extra compensation will be allowed for concrete required to fill an oversized casing or oversized excavation. All casings, except permanent casings, shall be removed from shaft excavations. Any length of permanent casing installed below the shaft cutoff elevation, shall remain in place.

When the shaft extends above ground or through a body of water, the portion exposed above ground or through a body of water may be formed with removable casing except when the permanent casing is specified. Removable casing shall be stripped from the shaft in a manner that will not damage the concrete. Casings can be removed when the concrete has attained sufficient strength provided: curing of the concrete is continued for a 72-hour period; the shaft concrete is not exposed to salt water or moving water for 7 days; and the concrete reaches a compressive strength of at least 2500 psi, as determined from concrete cylinder breaks.

16-Temporary Casing: All subsurface casing shall be considered temporary unless specifically shown as permanent casing in the contract documents. The Contractor shall be required to remove temporary casing before or immediately after completion of concreting the drilled shaft. Casing should never be pulled after the concrete begins to set due to probable entrapment of drilling fluid in the shaft concrete and probable separation of the concrete within the shaft

If the Contractor elects to remove a casing and substitute a longer or larger-diameter casing through caving soils, the excavation shall be either stabilized with slurry or backfilled before the new casing is installed. Other methods, as approved by the Engineer, may be used to control the stability of the excavation and protect the integrity of the foundation materials.

Before the casing is withdrawn, the level of fresh concrete in the casing shall be a minimum of 5 feet above either the hydrostatic water level in the formation or the level of drilling fluid in the annular space behind the casing, whichever is higher. As the casing is withdrawn, care shall be exercised to maintain an adequate level of concrete within the casing so that fluid trapped behind the casing is displaced upward and discharged at the ground surface without contaminating or displacing the shaft concrete.

Temporary casings that become bound or fouled during shaft construction and cannot be practically removed shall constitute a defect in the drilled shaft. The Contractor shall be responsible to improve such defective shafts to the satisfaction of the Engineer. Such improvement may consist of, but is not limited to, removing the shaft concrete and extending the shaft deeper to compensate for loss of frictional capacity in the cased zone, providing straddle shafts to compensate for capacity loss, grouting around the exterior of the shaft, or providing a replacement shaft. All corrective measures including redesign of footings caused by defective shafts shall be done to the satisfaction of the Engineer by the Contractor without either compensation or an extension of the completion date of the project. In addition, no compensation will be paid for casing remaining in place.

17-Permanent Casing: Permanent casing shall be used when specified by the contract documents. The casing shall be continuous between top and bottom elevations prescribed in the plans. After installation is complete, the permanent casing shall be cut off at the prescribed elevation.

In cases where special temporary casings are shown on the plans or authorized in writing by the Engineer to be used in conjunction with permanent casing, the Contractor shall maintain both alignment of the temporary casing with the permanent casing and a positive, watertight seal between the two casings during excavation and concreting operations.

Permanent casing shall maintain intimate contact with the surrounding earth after installation. Use of an oversized hole or temporary casing outside the permanent casing beneath the ground surface will not be allowed without written permission by the Engineer. Should an oversized hole or temporary casing outside the permanent casing beneath the ground surface be allowed by the Engineer, grouting of the exterior annular space shall be provided by the Contractor to create intimate contact between the casing and the surrounding ground. The grouting shall extend from the bottom of the annular space to an elevation determined by the Engineer. No compensation will be paid to the Contractor for grouting of the exterior annular space.

18-Slurry: Mineral or polymer slurries shall be employed when slurry is used in the drilling process unless other drilling fluids are approved in writing by the Engineer. Mineral slurry shall have both a mineral grain size that will remain in suspension and sufficient viscosity and gel characteristics to transport excavated material to a suitable screening system. The percentage and specific gravity of the material used to make the mineral suspension shall be sufficient to maintain the stability of the excavation and to allow proper concrete placement.

During construction, the level of the slurry shall be maintained at a height sufficient to prevent caving of the hole. The slurry head shall remain above the piezometric head of the groundwater. This includes initial drilling of the borehole down to the piezometric level. Slurry should be introduced when the depth of the borehole is still above the piezometric level, not after the inflow of water can be detected and/or sloughing has begun. In the event of a sudden significant loss of slurry to the hole, the construction of that foundation shall be stopped until either a method to stop slurry loss or an alternate construction procedure has been approved by the Engineer.

Mineral slurry shall be premixed thoroughly with clean fresh water and adequate time (as prescribed by the mineral manufacturer) allotted for hydration prior to introduction into the shaft excavation. Slurry tanks of adequate capacity will be required for slurry circulation, storage, and treatment. No excavated slurry pits will be allowed in lieu of slurry tanks without the written permission of the Engineer. Desanding equipment shall be provided by the Contractor as necessary to control slurry sand content to less than 4 percent by volume at any point in the borehole at the time the slurry is introduced, including situations in which temporary casing will be used. The Contractor shall take all steps necessary to prevent the slurry from "setting up" in the shaft. Such methods may include but are not limited to: agitation, circulation and/or adjusting the properties of the slurry. Disposal of all slurry shall be done off site in suitable areas by the Contractor. Disposal of the slurry shall also be in conformance with Article 1.10 of the Standard Specifications.

Control tests using suitable apparatus shall be carried out on the mineral slurry by the Contractor to determine density, viscosity and pH. An acceptable range of values for those physical properties is shown in the table given in this section:

MINERAL SLURRY
(Sodium Bentonite or Attapulgite in Fresh Water)

	Acceptable Range of Values		
Property (Units)	At Time of Slurry Introduction	In Hole at Time of Concreting	Test Method
Density (pcf)	64.3* - 69.1*	64.3* - 75.0*	Density Balance
Viscosity (sec. /quart)	28 - 45	28 - 45	Marsh Funnel
pH	8 - 11	8 - 11	pH paper, pH meter

* Increase by 2 pcf in salt water

Notes: a. Tests should be performed when the slurry temperature is above 40 degrees Fahrenheit.

b. If desanding is required; sand content shall not exceed 4 per cent (by volume) at any point in the borehole as determined by the American Petroleum Institute sand content test when the slurry is introduced.

Tests to determine density, viscosity and pH value shall be performed during the shaft excavation to establish a consistent working pattern. A minimum of four sets of tests shall be made during the first 8 hours of slurry use. When the results show consistent behavior the testing frequency may be decreased to one set every four hours of slurry use.

If the Contractor proposes to use polymer slurry, either natural or synthetic, the product is subject to approval by the Engineer. Slurry properties at the time of mixing and at the time of concreting must be in conformance with the written recommendations of the manufacturer. However, whatever product is used, the sand content at the base of the drilled shaft excavation shall not exceed 1 per cent when measured by Method API 13B-1, Section 5, immediately prior to concreting.

If the Contractor proposes to use blended mineral-polymer slurry, the Contractor shall submit a detailed report specific to the project prepared and signed by a qualified slurry consultant describing the slurry materials, the mix proportions, mixing methods and quality control methods.

If polymer slurry, or blended mineral-polymer slurry, is proposed, the Contractor's slurry management plan shall include detailed provisions for controlling the quality of the slurry, including tests to be performed, the frequency of those tests, the test methods, and the maximum and/or minimum property requirements that must be met to ensure that the slurry meets its intended functions in the subsurface conditions at the construction site and with the construction methods that are to be used. The slurry management plan shall include a set of the slurry manufacturer's written recommendations and shall include the following tests, as a minimum: Density test (API 13B-1, Section 1), viscosity test (Marsh funnel and cup, API 13B-1, Section 2.2, or approved viscometer),

pH test (pH meter, pH paper), and sand content test (API sand content kit, API 13B-1, Section 5).

If approved by the Engineer, the Contractor may use only water as a drilling fluid. In that case, all of the provisions in the table shown in this section for mineral slurries shall be met, except that the maximum density shall not exceed 70 pcf.

The Contractor shall insure that a heavily contaminated slurry suspension, which could impair the free flow of concrete, has not accumulated in the bottom of the shaft. Prior to placing concrete in any shaft excavation, the Contractor shall take slurry samples using a sampling tool approved by the Engineer. Slurry samples shall be extracted from the base of the shaft and at intervals not exceeding 10 feet up the slurry column in the shaft, until two consecutive samples produce acceptable values for density, viscosity, and pH.

When any slurry samples are found to be unacceptable, the Contractor shall take whatever action is necessary to bring the slurry within specification requirements. Concrete shall not be poured until the slurry in the hole is re-sampled and test results produce acceptable values.

Reports of all tests required above signed by an authorized representative of the Contractor, shall be furnished to the Engineer on completion of each drilled shaft.

During construction, the level of mineral or blended mineral-polymer slurry in the shaft excavation shall be maintained at a level not less than 4 feet above the highest expected piezometric pressure head along the depth of the shaft, and the level of polymer slurry shall be maintained at a level not less than 6 feet above the highest expected piezometric pressure head along the shaft. If at any time the slurry construction method fails, in the opinion of the Engineer, to produce the desired final results, then the Contractor shall both discontinue this method and propose an alternate method for approval of the Engineer.

Drilling tools should contain vents to stabilize hydrostatic pressure above and below the tool during insertion and extraction. The rate of tool extraction should not cause any noticeable turbulence in the slurry column in the borehole.

The Contractor shall retain the slurry manufacturer's technical representative to be present at the site during project startup, or throughout the entire project if continual difficulty is expected, to ensure that the slurry is mixed and managed properly.

19-Excavation Inspection: The Contractor shall check the dimensions and alignment of each shaft excavation. Final shaft depths shall be measured with a suitable weighted tape or other approved methods after final cleaning. The Contractor shall provide equipment and access to the Engineer for confirming dimension, alignment, and bottom cleanliness. Required shaft cleanliness will be determined by the Engineer.

20-Construction Tolerances: The following construction tolerances apply to drilled shafts unless otherwise stated in the contract documents:

(a) The center of the drilled shaft shall be within 3 inches of plan position in the horizontal plane at the plan elevation for the top of the shaft.

(b) The vertical alignment of a vertical shaft excavation shall not vary from the plan alignment by more than 1/4 inch per foot of depth.

(c) After all the concrete is placed, the top of the reinforcing steel cage shall be no more than 6 inches above and no more than 3 inches below plan position.

(d) All casing diameters shown on the plans refer to outside diameter (OD) dimensions. The dimensions of casings are subject to American Pipe Institute tolerances applicable to regular steel pipe. When approved, the Contractor may elect to provide a casing larger in diameter than shown in the plans.

(e) The top elevation of the shaft shall have a tolerance of plus 1 inch or minus 3 inches from the plan top-of-shaft elevation.

(f) Excavation equipment and methods shall be designed so that the completed shaft excavation will have a planar bottom. The cutting edges of excavation equipment shall be normal to the vertical axis of the equipment within a tolerance of +/– 3/8 inch per foot of diameter.

Drilled shaft excavations and completed shafts not constructed within the required tolerances are unacceptable. The Contractor shall be responsible for correcting all unacceptable shaft excavations and completed shafts to the satisfaction of the Engineer. Materials and work necessary, including engineering analysis and redesign, to complete corrections for out-of-tolerance drilled shaft excavations shall be furnished without either cost to the State or an extension of the completion date of the project.

21-Reinforcing Steel Cage Construction and Placement: The reinforcing steel cage, consisting of longitudinal bars, ties, cage stiffener bars, spacers, centralizers, and other necessary appurtenances, shall be completely assembled and placed as a unit immediately after the shaft excavation is inspected and accepted, and prior to concrete placement. Internal stiffeners shall be removed as the cage is placed in the borehole so as not to interfere with the placement of concrete.

The reinforcing steel in the shaft shall be tied and supported so that the reinforcing steel will remain within allowable tolerances given in this specification. Concrete spacers or other approved noncorrosive spacing devices shall be used at sufficient intervals near the bottom and at intervals not exceeding 10 feet up the shaft to ensure concentric spacing for the entire cage length. Spacers shall be constructed of approved material equal in quality and durability to the concrete specified for the shaft. The spacers shall be of adequate dimension to insure a minimum 3 inch annular space between the outside of the reinforcing cage and the side of the excavated hole. Approved cylindrical concrete feet (bottom supports) shall be provided to insure that the bottom of the cage is maintained the proper distance above the base.

The elevation of the top of the steel cage shall be checked before and after the concrete is placed. If the upward displacement of the rebar cage exceeds 2 inches or if the downward displacement exceeds 6 inches per 20 feet of shaft length, the drilled shaft will be considered defective. Corrections shall be made by the Contractor to the satisfaction of the Engineer. No additional shafts shall be constructed until the Contractor has modified his rebar cage support in a manner satisfactory to the Engineer.

22-Concrete Placement: Concrete placement shall be performed in accordance with the applicable portions of the general specifications on concrete materials of this specification and with the requirements herein.

Concrete shall be placed as soon as possible after reinforcing steel placement and after the Engineer has accepted the cleanliness of the shaft. The Engineer may re-inspect the shaft for cleanliness should there be any delays between initial acceptance of shaft cleanliness and commencement of the concrete pour. If during the delay the Engineer has determined that shaft cleanliness has deteriorated, the Engineer may require the Contractor to re-clean the shaft If necessary, the Contractor may be required to remove the cage, should it be necessary to achieve the required shaft cleanliness. The Contractor shall not be compensated for any cost and/or lost of time due to the need for re-cleaning of the shaft.

Concrete placement shall be continuous from the bottom to the top elevation of the shaft. Concrete placement shall continue after the shaft excavation is filled until good quality concrete is evident at the top of shaft. Concrete shall be placed either by free fall or through a tremie or concrete pump. The free fall placement shall only be permitted in dry holes. Concrete placed by free fall shall fall directly to the base without contacting either the rebar cage or hole sidewall. Drop chutes may be used to direct concrete to the base during free fall placement.

The Contractor shall maintain a Concreting Logs during all pours. The log shall include, but not necessarily be limited to, concreting curves that shall plot Depth to Top of Concrete vs. Volume of Concrete Poured (for both theoretical and actual volumes of concrete poured) The Contractor shall provide the Engineer a copy of each log upon completion of each drilled shaft pour. A sample of the proposed log to be used by the Contractor shall be submitted as part of the installation plan working drawing submittal.

23-Tremies: Tremies may be used for concrete placement in either wet or dry holes. Tremies used to place concrete shall consist of a tube of sufficient length, weight, and diameter to discharge concrete at the shaft base elevation. The tremie shall not contain aluminum parts that will have contact with the concrete. The tremie inside diameter shall be at least 6 times the maximum size of aggregate used in the concrete mix but shall not be less than 10 inches. The inside and outside surfaces of the tremie shall be clean and smooth to permit both flow of concrete and unimpeded withdrawal during concreting. The wall thickness of the tremie shall be adequate to prevent crimping or sharp bends, which restrict concrete placement.

The tremie used for wet excavation concrete placement shall be watertight. Underwater or under-slurry placement shall not begin until the tremie is placed to the shaft base elevation, and the concrete shall be kept completely separated from the water or slurry prior to the time it is discharged. Valves, bottom plates or plugs may be used for this purpose only if concrete discharge can begin within one tremie diameter of the base of the drilled shaft. Plugs shall either be removed from the excavation or be of a material, approved by the Engineer, which will not cause a defect in the shaft if not removed. The discharge end of the tremie shall be constructed to permit the free radial flow of concrete during placement operations. The tremie discharge end shall be immersed at least 5 feet in concrete at all times after starting the flow of concrete. The flow of the concrete shall be continuous. The level of the concrete in the tremie shall be maintained above the level of slurry or

water in the borehole at all times to prevent water or slurry intrusion into the shaft concrete.

If at any time during the concrete pour, the tremie line orifice is removed from the fluid concrete column and discharges concrete above the rising concrete level, the shaft shall be considered defective. All costs of repair or replacement of defective shafts shall be the responsibility of the Contractor.

24-Pumped Concrete: Concrete pumps and lines may be used for concrete placement in either wet or dry excavations. All pump lines shall have a minimum 4 inch diameter and be constructed with watertight joints. Concrete placement shall not begin until the pump line discharge orifice is at the shaft base elevation.

For wet excavations, a plug or similar device shall be used to separate the concrete from the fluid in the hole until pumping begins. The plug shall either be removed from the excavation or be of a material, approved by the Engineer, that will not cause a defect in the shaft if not removed.

The discharge orifice shall remain at least 5 feet below the surface of the fluid concrete. When lifting the pump line during concreting, the Contractor shall temporarily reduce the line pressure until the orifice has been repositioned at a higher level in the excavation.

If at any time during the concrete pour the pump line orifice is removed from the fluid concrete column and discharges concrete above the rising concrete level, the shaft shall be considered defective. All costs of repair or replacement of defective shafts shall be the responsibility of the Contractor.

25-Drop Chutes: Drop chutes may be used to direct placement of free-fall concrete in excavations where the maximum depth of water does not exceed 3 inches. Free fall placement is not permitted in wet excavations. Drop chutes shall consist of a smooth tube of either one piece construction or sections that can be added and removed. A drop chute can also be a hopper with a short tube to direct the flow of concrete. Concrete may be placed through either the hopper at the top of the tube or side openings as the drop chute is retrieved during concrete placement. If concrete placement causes the shaft excavation to cave or slough, or if the concrete strikes the rebar cage or sidewall, the Contractor shall reduce the height of free fall and/or reduce the rate of concrete flow into the excavation. If caving or sloughing of the borehole walls occurs during free-fall placement of concrete, the shaft shall be considered defective. All costs of repair or replacement of defective shafts shall be the responsibility of the Contractor. If concrete placement cannot be satisfactorily accomplished by free fall in the opinion of the Engineer, the Contractor shall use either tremie or pumping techniques to accomplish the pour.

26-Acces Tubes for Cross Hole Acoustic Logging: Access tubes for crosshole acoustic logging shall be placed on each reinforcing cage designated in the contract documents in the position and at the frequency shown on the plans. Access tubes must be firmly secured to the cage. Normally, the tubes should extend from 6 inches above the bottom of the shaft to at least 3 feet above the top of the shaft, or 2 feet above the ground surface if the shaft is cut off below the ground surface. If crosshole acoustic tests are to be performed, the access tubes should be filled with clean water no later than 4 hours after placement of the concrete and the tubes capped during concrete placement to keep out concrete and debris. In all cases the access tubes should be as nearly parallel as possible

and should be placed as far from the longitudinal steel bars as possible.

Prior to the beginning of downhole logging, the Contractor shall assure that the CSL test probes can pass through every tube to the bottom. If a tube is obstructed, the entire length of the obstructed access tube will not be measured for payment. The Engineer may also require the Contractor to core a hole within the drilled shaft near the obstructed tube to the full depth of the obstructed access tube. The cored hole shall be large enough to accommodate the test probe for the full length of the hole. The coring equipment, coring procedure and location of the core hole shall be approved by the Engineer prior to beginning the coring process. The coring method shall provide for complete core recovery and shall minimize abrasion and erosion of the core. The core hole shall be placed at a position in the shaft that will not produce damage to the reinforcing steel in the shaft. The core hole shall be logged, voids or defects indicated on the log and the log submitted to the Engineer. Cores shall be preserved and made available for inspection by the Engineer. The core hole will be treated as an access tube and downhole testing shall then commence. Core holes that are drilled for the purpose providing a substitution for a blocked access tube shall be measured and paid for at the contract unit price for Access Tubes.

Upon completion of all tests involving access tubes and after acceptance of the drilled shaft, the access tubes and core holes shall be filled with grout.

27-Evaluation and Acceptance/Rejection of Drilled Shafts: Upon completion and testing (if called for) of a drilled shaft, the Engineer shall review all available drilling logs, drilled shaft construction logs, concreting logs, inspection reports, load test results, and/or integrity test results to determine the acceptability of the drilled shaft. If the Engineer determines that available data in inconclusive, the Engineer may call for additional testing, coring, or other appropriate actions necessary for evaluating the acceptability of the drilled shaft. Should the additional testing confirm the presence of anomalies, the Contractor shall not be compensated for the cost of the additional testing (even if the anomalies are determined to be non-critical and the shaft is found to be acceptable). Should additional testing demonstrate that anomalies are not present (prior to any remedial work), the additional testing shall be paid for by the Department. The Contractor may continue to construct drilled shafts before receipt of notice of acceptance of the tested shaft or shafts by the Engineer. If the Engineer finds previously constructed shaft(s) to be unacceptable, the Contractor shall be required to repair, at the Contractor's expense, the unacceptable shaft(s) to the satisfaction of the Engineer. The Contractor shall prove to the satisfaction of the Engineer, at no expense to the State, the acceptability of all shafts constructed since the time that the unacceptable shaft was constructed and the acceptability of the procedure to construct future shafts. If the Engineer deems the construction procedure to be unacceptable, the Contractor shall cease all drilled shaft construction until a new construction procedure is submitted by the Contractor and accepted by the Engineer.

The Contractor shall submit any repair procedures to the Engineer for review and approval. If these plans involve change or impact the structural design of the shafts or shaft caps, or to the geometry of the shafts, any redesign proposed in the Contractor's plan shall be performed at the Contractor's expense by a qualified Professional Engineer registered in the State of Connecticut.

The Engineer may require that additional shafts be tested. If the testing of the additional shaft(s) indicates the presence of a defect in any additional shaft, the testing cost for that shaft will

be borne by the Contractor and the Contractor shall repair the shaft at the Contractor's expense, as above. Any additional testing required by the Engineer on repaired drilled shafts shall be considered part of the Contractors remediation plan and its cost shall be borne by the Contractor.

Method of Measurement:

1-Furnishing Drilled Shaft Drilling Equipment: There will be no measurement of the work performed under this item.

2-Drilled Shaft: The quantities to be paid for shall be the length in feet of the completed and accepted concrete drilled shaft of the diameter and containing the reinforcement shown on the plans. The length shall be determined as the difference between the plan top of shaft elevation and the final bottom of shaft elevation.

3- Drilled Shaft Earth Excavation: The quantities to be paid shall be the length in feet of completed earth excavation of the diameter shown on the plans measured in linear feet along the centerline of the shaft either from the top of exiting grade elevation prior to drilling or from the bottom of the drilled shaft cap elevation (whichever is lower) to either the top competent rock elevation (if the drilled shaft extends onto or into competent rock) or to the bottom of the shaft elevation (if the shaft does not extend onto or into competent rock).

4- Drilled Shaft Rock Excavation: The quantity to be paid shall be the length in feet of completed rock excavation of the diameter shown on the plans measured in linear feet along the centerline of the shaft from the top of competent rock elevation to the bottom of the shaft elevation.

5-Obstructions: The quantities to be paid shall be the number of hours of work, or fraction thereof per obstruction, after designation as an obstruction by the Engineer, required to remove the obstruction.

6-Trial Drilled Shaft: The quantity to be paid shall be the authorized linear feet of trial shaft holes drilled to the diameter shown on the plans, completed (including backfill when required) and accepted. The linear feet of trial shaft holes shall be determined as the difference between the existing ground surface elevation at the center of the trial shaft hole prior to drilling and the authorized bottom elevation of the hole.

7-Exploration Test Borings: The quantity to be paid shall be the length in linear feet, measured from the existing grade elevation to the bottom elevation of the exploration hole, for each authorized exploration boring drilled.

8-Permanent Casing: The quantity to be paid shall be the linear feet of each size casing used. The length to be paid for shall be measured along the casing from the top of the shaft elevation or the top of casing, whichever is lower, to the bottom of the casing at each shaft location where permanent casing is used.

9-Access Tubes: The quantity to be paid will be per linear foot of unobstructed access tube, installed and accepted in the drilled shafts, to the depths shown on the plans.

Basis of Payment:

1-Furnishing Drilled Shaft Drilling Equipment: Payment for this item when made at the contract lump sum amount will be full and complete payment for furnishing and moving the drilling equipment to the project site, setting the equipment up at the locations removing the equipment from the project site. Payment of 60 per cent of the amount bid for this item will be made when all drilling equipment is on the project site, assembled and ready to drill foundation shafts. Payment for the remaining 40 per cent of the bid amount will be made when all shafts have been drilled, all shaft concrete has been placed up to the top of the shaft, all defects are repaired, and all drilled shafts have been accepted by the State.

2-Drilled Shaft: Drilled shafts shall be paid for at the contract unit price per linear foot for drilled shaft of the diameter specified. Such payment shall include the cost of concrete and reinforcing steel, all labor, materials, equipment, temporary casings, slurry, blasting, protection of existing facilities/utilities and incidentals necessary to complete the drilled shaft.

3- Drilled Shaft Earth Excavation: Earth excavation shall be paid at the contract unit price per linear foot for drilled shaft earth excavation of the diameter specified. Such payment shall be full compensation for all labor, materials, water control, disposal of excavated material and equipment necessary to complete the work in an acceptable fashion. .

4-Drilled Shaft Rock Excavation:. Drilled shaft rock excavation shall be paid at the contract unit price per linear foot for drilled shafts rock excavation of the diameter specified. Such payment shall be full compensation for all labor, materials, water control, disposal of excavated material and equipment necessary to complete the work in an acceptable fashion. No payment will be made for additional rock excavation or placement of additional shaft concrete resulting from blasting overbreak.

5-Obstructions: Removal of obstructions shall be paid at the contract unit price per hour for obstructions. Such payment shall be full compensation for all labor, materials, excavation of obstructions, water control, disposal of excavated material, and equipment necessary to complete the work.. If the Contractor chooses to use a larger shaft diameter for obstruction excavation, no additional compensation will be provided to perform this oversized obstruction excavation. The contract unit price shall not be greater than the minimum allowable contract unit price nor higher than the maximum allowable contract unit price as shown on the plans or in the contract documents.

6-Trial Drilled Shaft: Trial drilled shafts of the specified diameter will be paid for at the contract unit price per linear foot for trial drilled shaft. Such payment shall be full compensation for excavating the trial drilled shaft through whatever materials are encountered to the bottom of shaft

elevation shown on the plans or as authorized by the Engineer (using slurry approved by the Engineer as necessary), providing inspection facilities, backfilling the hole, restoring the site as required and all other expenses to complete the work.

7-Exploration Test Borings: Soil samples and/or rock cores of the diameter and length required and authorized by the Engineer will be paid for at the contract unit price per linear foot. Such payment shall be full compensation for drilling, extracting, packaging and classifying samples or cores, delivering them to the Engineer, furnishing concrete or grout to fill the core hole, providing a written log of the hole and all other expenses necessary to complete the work.

8-Permanent Casing: Permanent casings shall be paid for at the contract price per linear foot for permanent casing of the diameter specified. Such price and payment shall be full compensation for furnishing and placing the permanent casing in the shaft excavation.

9-Access Tubes: This item will be paid for at the unit contract price per linear foot of unobstructed access tube, installed in the drilled shafts, to the depths shown on the plans and the post test grouting of the access tubes.