SECTION 503 – DRILLED SHAFT FOUNDATIONS

503.01 DESCRIPTION

This Section describes the requirements for installing and testing drilled shafts.

503.02 MATERIALS

503.02.01 Materials

Provide materials as specified:	
Concrete	903.03
Self Consolidating Concrete	903.06.01
Grout	903.08.02
Reinforcement Steel	905.01.01
Drilled Shaft Casing	906.03
Structural Steel Paint (Organic Zinc)	912.01.01
Water	919.08

Provide clay-mineral based slurry (processed attapulgite or bentonite) for mineral slurry. Ensure that the mineral slurry has a mineral grain size that will remain in suspension and has sufficient viscosity and gel characteristics to transport excavated material to a suitable screening system. Ensure that the percentage and specific gravity of the material used to make the mineral suspension is sufficient to maintain the stability of the excavation and to allow proper concrete placement.

Provide polymer slurry as recommended by the manufacturer.

503.02.02 Equipment

Provide equipment as specified:	
Concrete Batching Plant	1010.01
Concrete Trucks	1010.02

Ensure that equipment does not introduce uncontrolled exhaust fumes into the surrounding areas, or other occupied areas adjacent to the work site. Crane and drilling engine exhaust fumes will require their own separate exhaust systems adequately vented to the atmosphere away from any confined work sites.

Ensure that equipment used for final bottom cleaning does not have a centralizing guide at the tip.

Use excavation and drilling equipment having adequate capacity, including power, torque, and down thrust to excavate a hole of both the maximum specified diameter and to a depth of 20 percent beyond the depths shown on the plans when operated at rated capacity.

Provide Crosshole Sonic Logging (CSL) test equipment that includes the following components:

1. A microprocessor-based CSL system for display of individual CSL records, analog-digital conversion and recording of CSL data, analysis of receiver responses, and printing of CSL logs.
2. Ultrasonic source and receiver probes for 1.5-or 2-inch inner diameter pipe, as appropriate.
3. An ultrasonic voltage pulser to excite the source with a synchronized triggering system to start the recording system.
4. A depth measurement device to determine and record depths.
5. Appropriate filter/amplification and cable systems for CSL testing.

503.03 CONSTRUCTION

503.03.01 Installation Plan

No later than 30 days after the date of the Notice to Proceed, submit to the RE for approval an installation plan that includes the following:

1. Names and descriptions of the last 3 drilled shaft construction projects completed, including the names and telephone numbers of owner's representatives.
2. Type, size, and number of equipment to be used.
3. Details of the overall construction operation sequence and the proposed sequence of shaft construction.
4. Details of planned shaft excavation methods.
5. Details of the methods to ensure shaft stability during excavation and concrete placement. Include a review of method suitability to the anticipated work site and subsurface conditions. If casings are proposed or required, provide casing dimensions, detailed procedures for permanent casing installation, and procedures for temporary casing installation and removal.
6. When slurry is specified or proposed, provide details of the methods for mixing, placing, circulating, and desanding the slurry. Also include the method of monitoring and continuously maintaining the slurry level. Provide the method of disposal.
7. Details of methods to clean and maintain the shaft excavation, including removal of loose rock and sediment from the shaft bottom.
8. Details of steel reinforcement lifting, splicing if necessary in a hanging position, insertion and securing, including support and centralization methods.
9. Mix design of the concrete and documentation showing that the mix design meets the approved mix and strength requirements.
10. The method used to fill or eliminate voids between the plan shaft diameter and excavated shaft diameter, or between the shaft casing and surrounding soil, if permanent casing is specified.
11. Methods to determine drilled shaft dimensions and the deviation from vertical for the entire depth of the drilled shaft.
12. Details of proposed methods to check shaft bottom cleanliness.
13. Procedures for control and removal of spoils on land, over water, or both.

14. Details of concrete batching and/or delivery to the work site, and concrete placement, including proposed operational procedures for concrete pump or tremie. Discuss the initial placement, raising tremie pipe(s) during placement, overfilling of the shaft concrete, the proposed 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.
15. The qualification records of the testing organization to perform the O-Cell Load Test and the CSL.
16. Details of procedures, materials, and equipment for performing the O-Cell Load Test and the CSL. Provide a certificate of calibration for the load cell from an approved testing laboratory. Ensure that the calibration was performed for all ranges of proposed loading within the 2 months preceding the load tests. Ensure that the certified accuracy of the load cell is within 1 percent of the true load.
17. Concrete core drilling equipment and procedures to retrieve the core specimens that may be required to determine the integrity of concrete placed in the drilled shaft.

The RE will schedule a review meeting between the Contractor, designer, and the Department after reviewing the installation plan and at least 15 days before the start of work.

Within 30 days after receipt of the plan, the RE will notify the Contractor of any additional information required and changes that may be necessary.

If the RE rejects the plan or a part of the plan, submit revisions to the RE for reevaluation. The RE will notify the Contractor within 10 days after receipt of proposed changes of their acceptance or rejection.

503.03.02 Demonstration Drilled Shaft Installation

The Department will require a demonstration drilled shaft to verify the Contractor's methods. Locate the demonstration shaft as shown on the Plans or as directed by the RE. Excavate the demonstration shaft to the depth of the deepest production shaft shown on the Plans. Construct the demonstration shaft as specified in 503.03.06. Include CSL as specified in 503.03.04.

Cut-off the concreted demonstration shafts 2 feet below finished grade or 3 feet below the mudline if in water. Restore disturbed areas at demonstration shaft holes to their original condition.

Once approval has been given to construct production shafts, do not change the personnel, methods, or equipment that were used to construct the approved demonstration shaft without written approval of the RE.

503.03.03 Load Tests

A. **O-Cell Installation.** Ensure that the installation and execution of the O-cell load tests are supervised by a Professional Engineer. Ensure that the O-cell, vibrating wire strain gauges, hydraulic supply, and other attachments are assembled according to the

manufacturer's recommendations. Provide a reinforcement steel cage, as specified in 503.03.06.K, to attach the O-cell. Excavate using the approved method at the location shown on the Plans. After excavating a test drilled shaft, and obtaining approval from the RE, place a seating layer of concrete in the base of the drilled shaft. While the seating concrete is still plastic, install the reinforcement steel cage with the O-cell in the test shaft so that the O-cell rests firmly in the concrete.

After seating the O-cell assembly, place concrete in the drilled shaft as specified in 503.03.06.M. The ME will take at least 6 concrete compression test cylinders from the concrete used in the test shaft. At least 1 day before the load test, the ME will test at least 1 of the cylinders. The ME will test at least 2 cylinders on the day of the load test. Do not perform the O-cell test until 7 days after placing the concrete and the concrete achieves the specified compressive strength.

B. **Load Testing and Reporting.** Perform load tests according to ASTM D 1143. If the test apparatus shows signs of negative effects due to the construction activities, immediately cease testing and do not resume until the conditions are favorable for testing. Apply loads in increments equaling 10 percent of the maximum test load for the drilled shaft.

Take direct movement indicator measurements of the following:

1. Downward drilled shaft end-bearing movement (1 indicator required).
2. Upward top-of-drilled shaft movement (minimum of 3 indicators required).
3. Vibrating wire strain gauges (minimum of 8 per test required).

Apply loads at the specified intervals until the maximum test load shown on the Plans is reached in either end bearing or side shear or until the maximum capacity or maximum stroke of the O-cell is reached. In addition to the requirements of ASTM D 1143, at each load increment, or decrement, take readings of the movement indicators at 1.0, 2.0, and 4.0 minute intervals while holding the load constant. Ensure that strain gauge readings are concurrent with shaft movement readings. The RE may direct additional cycles of loading and unloading using similar procedures following the completion of the test cycle.

Ensure that dial gauges or Linear Variable Displacement Transducers (LVDTs) used to measure end bearing, side shear movement, and shaft compression have a minimum travel of 8 inches and are capable of being read to the nearest 0.0001 inch division. The Contractor may alternately monitor end bearing movement using LVDTs capable of measuring the expansion of the O-cell (6 inches). Ensure that the reference beam has a minimum length equal to 6 times the drilled shaft diameter. Monitor the reference beam for movement during load testing using a surveyor's level.

Provide the performance results of each load test to the RE the day after performing the load tests. Provide a report of the load test results to the RE within 10 days of completing the test. Ensure that the report includes data readings and plots of the readings, the details of the load test and set-up, and a determination of the end bearing and friction/adhesion of the rock and soil. Within 20 days, the Department will notify the Contractor if revisions to the foundation lengths and installation procedures will be made based on the

results of the load tests. Do not begin construction of production drilled shafts without the Department's approval.

C. **Post-Test Grouting Procedures.** Grout the interior of the O-cell and annular space around the outside of the O-cell according to the manufacturer's recommendations. The Contractor does not have to grout test shafts that will not be used as production shafts.

503.03.04 Crosshole Sonic Logging (CSL)

A. **CSL Tube Installation.** Begin Crosshole Sonic Logging (CSL) on all production and demonstration drilled shafts 48 hours after placing concrete in the shaft. Ensure that the testing is completed within 20 days after placing concrete.

Ensure that the CSL tubes are watertight and have a round, regular, internal diameter free of defects or obstructions, including any at tube joints, to allow the free, unobstructed passage of 1.3-inch diameter source and receiver probes.

Ensure that each pipe is fitted with a watertight shoe at the bottom and a removable cap at the top. Attach the pipes securely to the interior of the reinforcement cage with a minimum cover of 4 inches. Install the tubes as near to parallel as possible.

Ensure that the tubes extend from 6 inches above the shaft bottoms to at least 3 feet above the shaft tops. If the shaft top is sub-surface, extend the tubes at least 2 feet above the ground surface. Ensure that joints required to achieve full-length tubes are watertight.

Ensure that the tubes are not damaged during reinforcement steel cage installation. As the cage is being lowered into the shaft, monitor the tubes to ensure that they are vertical and parallel, and that connections are watertight. After installing the reinforcement cage, immediately fill the tubes with clean water. After the tubes are filled with water, cap or seal the tube tops.

Before placing concrete, plumb at least 1 tube per shaft and record the tube length. Note the stickup of the tubes above the shaft tops.

Do not remove the seals or caps until the concrete in the shaft has set. Remove the caps or plugs after installation and ensure not to apply excess torque, hammering, or other stresses that could break the bond between the tubes and the concrete.

B. **CSL Testing and Reporting.** Perform CSL tests between pairs of tubes. Perform the CSL tests with the source and receiver probes in the same horizontal plane, unless the tests indicate potential defects. Take CSL measurements at depth intervals of 2 inches or less, from the bottom of the tubes to the top of each shaft. Pull the probes simultaneously, starting from the bottoms of the tubes, over a depth measuring device. Remove slack from the cables before pulling to provide for accurate depth measurements of the CSL records. Test 2 principle diagonals through the center and between each tube pair around the perimeter of tested shafts.

If the tests indicate potential defects, the RE may direct the Contractor to evaluate questionable zone using tomography (source and receiver vertically offset in the tubes). Report defects indicated by longer pulse arrival times and significantly lower amplitude/energy signals to the RE, and conduct additional tests as required to evaluate the extent of such defects.

The RE will reject a shaft based on conclusive evidence that a defect exists in the shaft that will result in inadequate or unsafe performance under service loads. If the CSL records are complex or inconclusive, the RE may require additional testing to confirm the location of the defect. The RE may require coring to verify shaft conditions.

Submit to the RE a report, signed and sealed by a Professional Engineer, that includes recommendations as to the acceptability, unacceptability, and soundness of the drilled shaft. Include in the report a CSL log for each tube pair tested with analyses of:

1. Initial pulse arrival time versus depth.
2. Pulse energy/amplitude versus depth.
3. Defect zones.

The Department will evaluate the CSL test results and determine whether or not the drilled shaft construction is acceptable. If the Department determines that the drilled shaft is acceptable, dewater the CSL tubes and grout.

503.03.05 Core Drilling of Drilled Shaft Concrete

The Contractor may core drill drilled shafts that are determined to be unacceptable based on the CSL tests. The RE will determine the number and depth of cores required. Drill cores at a minimum diameter of 3 inches.

Keep an accurate coring log, properly mark cores with the depth at each interval of core recovery, and place the cores in a crate. Deliver the cores and 3 copies of the coring log to the Department Laboratory.

If the RE determines that the drilled shaft is acceptable, dewater and grout the core holes and the CSL tubes.

If the Department determines that the drilled shaft is unacceptable, submit working drawings for approval proposing corrective measures. Do not begin corrective measures until the Department approves the working drawings.

Do not proceed with construction above a drilled shaft until the quality of the shaft, as represented by the core samples, is determined to be acceptable and the RE provides notification to continue construction.

503.03.06 Constructing Drilled Shafts

A. **Installation Plan.** Submit the installation plan, as specified in 503.03.01. Do not begin constructing drilled shafts until the RE approves the plan.

B. **Location and Alignment.** Construct drilled shafts within 3 inches of plan position in the horizontal plane at the elevation of the top of the shaft. Ensure that the vertical alignment of a shaft excavation does not vary from the plan alignment by more than 1/4 inch per foot of depth. Ensure that the alignment of a battered shaft excavation does not vary from the plan alignment by more than 1/2 inch per foot of depth.

C. **Construction Sequence Limitations.** Excavate to the bottom of the footing elevation before beginning shaft construction. When constructing drilled shafts and placing embankment, construct drilled shafts after the placement of embankment. Repair disturbances caused by shaft installation to a subsequent drilled shaft area before beginning shaft construction.

Do not excavate a shaft if an adjacent shaft in the same substructure unit is open unless the RE's written approval is obtained. Do not perform blasting or vibrate to place casings until the concrete in adjacent shafts has reached 80 percent of the required 28-day compressive strength. Once the excavation of a shaft has begun, do not stop the excavation until the excavation is completed. If the excavation is stopped for more than 24 hours, maintain shaft stability as detailed in the installation plan.

D. **Excavation Log.** Maintain an excavation log during shaft excavation that includes the following:

1. Description and approximate top and bottom elevation of each soil or rock material encountered during shaft excavation.
2. Elevations at which seepage or groundwater flow are encountered, and remarks.
3. The type of tools used for the excavation.
4. Changes in the type of tools used for excavation.

Ensure that discrepancies noted on the log by the RE are resolved by the end of each day. Provide 2 copies of the final log to the RE within 24 hours after a shaft excavation is completed and approved.

Reuse excavated material as specified in 202.03.07.A.

E. **Excavating.** Use the appropriate method for constructing drilled shafts as follows:

1. **Dry Method.** Only use the dry method where the groundwater level and soil conditions allow construction of the drilled shaft in a relatively dry excavation, and where the sides and bottom of the shaft may be visually inspected by the RE before placement of reinforcement and concrete. The dry method will consist of drilling the shaft excavation, removing any accumulated water and loose material from the excavation, placing the reinforcement cage, and concreting the shaft in less than 3 inches of water.

2. **Wet Method.** Construct drilled shafts using the wet method where dry excavation cannot be maintained. The wet method will consist of using water or slurry, as specified in 503.03.06.G, to maintain stability of the drilled shaft perimeter while excavating to finished depth, placing the reinforcement cage, and concreting the shaft. The Contractor may use the static or circulation process of the wet method.

   When the material encountered cannot be drilled using conventional earth drilling tools and equipment, provide rock drilling equipment, including air tools, approved blasting materials, and other equipment as necessary to construct the shaft excavation to the size and depth required. Obtain the RE's approval before switching from earth to rock drilling tools and equipment. Obtain the RE's approval before blasting.

   The Contractor may overream with a grooving tool, overreaming bucket, or other RE approved equipment. The RE will direct the thickness and extent of sidewall overreaming.

   The Department will require sidewall overreaming between 1/2 and 3 inches when the sidewall of the hole has either softened due to excavation methods, swollen due to delays in concreting, or degraded because of slurry cake buildup.

   Immediately remove drilling tools that are lost in the excavation.

F. **Constructing Using Casings.** Construct drilled shafts using casings where shown on the Plans or where the dry or wet construction methods are inadequate to prevent caving or excessive deformation of the hole. The Contractor may either place casings in a predrilled hole or advance casings through the ground by twisting, driving, or vibrating. When installing casings that are left in rock for the purpose of shielding voids, ensure that the predrilled hole is not more than 2 inches bigger than the casing diameter. When downsizing of permanent casing is required, do not overlap more than 6 feet of casing. .03.06

   When constructing drilled shafts in open water, extend the exterior casings from above the water elevation into the ground to protect the shaft concrete from water action during placement and curing of the concrete. Install the casing to ensure a positive seal at the bottom of the casing so that no seepage of water or other materials occurs into or from the shaft excavation.

   When casings are not shown on the Plans, but the Contractor believes that casings are necessary, the Contractor shall submit, in the installation plan, details of the proposed casing method (including casing lengths and diameters) and the proposed procedures of casing installation to the RE for review. If the Contractor does not determine the need for casings until after work on the shafts has begun, the Contractor shall submit to the RE for review a revised installation plan proposing the casing installation method for review.

   Ensure that casings are clean, round, straight, and free of weld breaks and holes that

would allow passage of water or plastic concrete. With RE approval, the Contractor may provide casings larger in diameter than shown on the Plans.

1. **Temporary Casings.** Casings are temporary unless shown as permanent casings on the Plans. Telescoping, predrilling with slurry, and overreaming to beyond the outside diameter of the casing may be required to install casing.

   Remove temporary casing before completing concrete placement in the drilled shaft. Before withdrawing the casing, ensure that the level of plastic concrete in the casing is at least 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, 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.
   50
   If the Contractor removes a specified diameter or length of casing and substitutes a longer or larger diameter casing through caving soils, the Contractor shall stabilize the excavation using a slurry or backfill before the new casing is installed.

   If temporary casings become bound or fouled during shaft construction and cannot be practically removed, the Department will designate the drilled shaft defective. Submit working drawings for approval proposing corrective measures. Do not begin corrective measures until the Department approves the working drawings.

2. **Removable Casing.** When the shaft extends above ground or through a body of water, the Contractor may use suitable, removable casing for the portion exposed above ground or through a body of water except when permanent casing is specified. Strip removable casing from the shaft and ensure that the concrete is not damaged.

   The Contractor may remove casings when the concrete has attained a strength of at least 2800 pounds per square inch as determined from 2 concrete cylinders field cured according to AASHTO T 23, provided that curing of the concrete is maintained, as specified in 504.03.02.F. Do not expose the shaft concrete to salt water or moving water for 7 days.

3. **Permanent Casings.** When not shown on the Plans, the Contractor may use permanent casing if approved by the RE. Ensure casings are continuous between the top and bottom elevations shown on the Plans. After installation is complete, cut off the permanent casing at the specified elevation.

   After installing the casings, repair damage to coated surfaces of the casings exposed to the air by applying an organic zinc prime coat from the same manufacturer as the shop-applied inorganic zinc prime coat.

G. **Constructing Using Slurries**. When using slurry to construct drilled shafts, the Contractor may use mineral or polymer slurries. During construction, maintain the level of the slurry at a height sufficient to prevent caving of the shaft excavation. Use a temporary surface casing in the upper soils. Maintain the slurry level inside the shaft above the groundwater level during installation and cleaning out. In the event of a sudden significant loss of slurry to the hole, cease the construction until either a method to stop slurry loss or an alternate construction procedure has been approved by the RE.

Pump slurry into holding tanks to ensure that no slurry spills or contaminates the site. Provide physical or chemical treatment of the slurry according to the manufacturer's recommendations.

During construction, maintain the level of mineral slurry in the shaft at least 4 feet above the highest expected piezometric pressure head that is along the depth of the shaft. Maintain the level of polymer slurry at least 5 feet above the highest expected piezometric pressure head that is along the shaft. If the selected slurry construction method fails, in the opinion of the RE, to produce the desired final results, cease this method and propose an alternate method to the RE for approval.

Ensure that a heavily contaminated slurry suspension, which could impair the free flow of concrete, has not accumulated in the bottom of the shaft. Before placing concrete for shaft excavation, take slurry samples using a sampling tool approved by the RE. Take slurry samples from the bottom of the shaft and at intervals not exceeding 10 feet up the slurry column in the shaft, until 2 consecutive samples produce acceptable values for density, viscosity, sand content, and pH at each sampling depth.

When slurry samples are unacceptable, take corrective actions. Do not place concrete until the slurry is re-sampled and test results are approved.

If the slurry remains in the shaft for more than 12 hours or if caking develops, roughen or re-ream the shaft with appropriate new bottom cleaning and slurry testing before concreting. Place concrete on the same day as the completion of the excavation of the drilled shaft to the bottom elevation.

1. **Mineral Slurry.** Premix mineral slurry with water and allow time for hydration according to the manufacturer's recommendations before using during shaft excavation. Provide slurry tanks of adequate capacity for slurry circulation, storage, and treatment. Do not substitute excavated slurry pits with slurry tanks without obtaining approval from the RE. Do not mix the slurry in the shaft.

   Monitor the properties of the pre-mixed slurry as it is introduced into the borehole and periodically thereafter, including a final check of a bottom sample before placing concrete to verify that the density and sand content are within the limits for the proper slurry displacement during concreting. Use desanding equipment 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.

Perform control tests on the mineral slurry in the presence of the RE to determine density, viscosity, and pH. Adjust the slurry to meet the requirements shown in Table 503.03.06-1:

Table 503.03.06-1 – Mineral Slurry[3]

Property	Range	Test
Density at time of slurry introduction	64.3 – 69.1[1] lbs/ft^3	API 13B, Bentonite Slurry Section (Mud Balance) ASTM D 4380
Density in hole at time of concreting	64.3 – 75.0[1] lbs/ft^3	API 13B, Bentonite Slurry Section (Mud Balance) ASTM D 4380
Viscosity at time of slurry introduction	28 – 45[2] sec/quart	API 13B, Section 2 (Marsh Funnel and Cup)
Viscosity in hole at time of concreting	28 – 45[2] sec/quart	API 13B, Section 2 (Marsh Funnel and Cup)
Sand content by volume	4% max	API 13B, Section 4 (Sand Screen Set) ASTM D 4381
pH at time of slurry introduction	8 – 11	API 13B, Section 6 (Paper Test Strips or Glass-Electrode pH Meter)
pH in hole at time of concreting	8 – 11	API 13B, Section 6 (Paper Test Strips or Glass-Electrode pH Meter)

[1] Increase by 2 lbs/ft^3 in salt water.

[2] Standard measurements are in seconds per quart. One sec/quart = 1.06 sec/liter.

a. Perform tests when the slurry temperature is above 40 °F.

b. Ensure that the sand content does not exceed 4 percent (by volume) at any point in the borehole as determined by the API sand content test when the slurry is introduced.

[3] Perform tests to determine density, viscosity and pH value during the shaft excavation to establish a consistent working pattern. Perform a minimum of 4 sets of tests during the first 8 hours of slurry use. When the results show consistent behavior, the Contractor may decrease the testing frequency to 1 set per every 4 hours of slurry use.

2. **Polymer Slurry.** Provide a slurry management plan to the RE that includes a set of the slurry manufacturer's written recommendations and results of the following tests, as a minimum:
    1. Density Test (API 13B-1, Section 1).
    2. Viscosity Test (Marsh funnel and cup, API 13B-1), Section 2.2 or approved viscometer.
    3. pH Test (pH meter, pH paper).
    4. Sand Content Test (API sand content kit, API 13B-1, Section 5).

    Also include the tests to be performed, the frequency of those tests, the test methods, and the maximum and minimum property requirements that must be met to ensure that the slurry meets its intended functions. Ensure that all test reports are signed, and provide them to the RE on completion of each drilled shaft.

H. **Removing Obstructions.** The RE will determine if an object is considered an obstruction. Remove surface and subsurface obstructions at drilled shaft locations. The Contractor may need to use special procedures and tools when the drilled shaft excavation cannot be advanced using conventional augers fitted with soil or rock teeth, drilling buckets or underreaming tools. Special procedures and tools may include: chisels, boulder breakers, core barrels, air tools, hand excavation, temporary casing, and increasing the hole diameter. Do not blast without obtaining written approval from the RE.

I. **Rock Socketing.** The RE will determine the top of rock sound enough for the Contractor to begin the socket based on the existing borings and observations during shaft drilling. The RE will not consider weathered or highly fractured rock as the top of rock socket.

    Prepare rock socket for concrete placement by roughening with drilling tools or by overreaming as directed by the RE. Rotate roughening tools against the rock socket area to remove accumulated slurry cake, to scale off loose rock fragments, and to roughen the finished rock socket surface.

J. **Excavation Cleaning and Verification.** Unless otherwise approved by the RE, ensure that at least 50 percent of the base of each shaft has less than 1/2 inch of sediment at the time of concrete placement. Ensure that the maximum depth of sediment or debris at any place on the base of the shaft does not exceed 1-1/2 inches.

    In the presence of the RE, determine the cleanliness of the bottom of the shaft by the use of sounding, probe data, video camera, tape with weight, or other methods approved by the RE. After final cleaning, determine the dimensions, depth, and alignment as directed by the RE.

K. **Constructing Reinforcement Steel Cages**. Immediately after the shaft excavation has been inspected and approved, assemble and place the reinforcement steel cage, consisting of longitudinal and transverse bars, ties, cage stiffeners, spacers, centralizers, and other necessary appurtenances before placing concrete. Remove internal stiffeners as the cage

is placed in the drilled shaft hole before placing concrete.

Use concrete spacers or other approved noncorrosive spacing devices 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. If the size of the spacers is not shown on the Plans, provide spacers that will create a minimum 3-inch annular space.

Provide cylindrical concrete supports to ensure that the bottom of the cage is maintained at the specified distance above the base.

L. **Concrete Placement Time Limitations.** Place concrete according to the limitations specified in 504.03.02.C. Continuously place concrete from the bottom to the top elevation of the shaft.

Ensure that the concrete placement is completed within 2 hours. The RE may allow the concrete placement time to exceed 2 hours if the Contractor demonstrates that the slump of the concrete will not be less than 4 inches during the entire time of concrete placement.

M. **Concrete Placement Methods**. The Contractor may request 1 additional set of cylinders to be taken for determining strength for early form removal as specified in 504.03.02.G. If additional cylinders are requested, notify the RE at least 24 hours before placing.

When using SCC to construct drilled shafts, only place SCC using the tremie method.

When using a concrete pump to place concrete for the drilled shaft, provide a standby pump that is immediately available if there is a pump failure.

Check the elevation of the top of the steel cage before, during, and after concrete placement. If the final upward displacement of the rebar cage exceeds 2 inches or if the downward displacement exceeds 6 inches per 20 feet of shaft length, the RE will reject the drilled shaft. Correct the shaft to the satisfaction of the RE. Do not construct additional shafts until the rebar cage support system is corrected.

1. **Tremie Method.** Ensure that tremie tubes are of sufficient length, weight, and diameter to discharge concrete at the shaft base elevation. Ensure that the inside and outside surfaces of the tremie are clean and smooth to allow the flow of concrete during concrete placement and an unimpeded withdrawal of the tremie tube after concrete placement. Ensure that the tremie tube's inside diameter is at least 6 times the maximum size of aggregate used in the concrete mix. Do not use tremie tubes less than 10 inches in diameter. Ensure that the tremie tube thickness is adequate to prevent crimping or sharp bends. Do not use tremie tubes that have aluminum parts that will come in contact with concrete. Ensure that the tremie tube is watertight.

   Do not begin placing concrete underwater until the tremie is placed to the shaft base elevation. The Contractor may use valves, bottom plates, or plugs to ensure concrete discharge begins within one tremie diameter of the base. Remove plugs from the excavation or construct them using a material that will not cause a defect

in the shaft if not removed. Construct the discharge end of the tremie to allow the free radial flow of concrete during placement operations.

Ensure that the tremie tube discharge end is immersed at least 5 feet in concrete at all times after starting the flow of concrete. Maintain a continuous flow of the concrete at a positive pressure differential to prevent water or slurry intrusion into the shaft concrete.

If the tremie tube discharge end is removed from the plastic concrete and discharges concrete above the rising concrete level, the RE will consider the drilled shaft defective. To correct this defect, the Contractor may: remove the reinforcement cage and concrete, complete necessary sidewall removal directed by the RE, and replace the shaft; or, the Contractor may replug the tremie tube, recharge with concrete, and insert a minimum of 5 feet below the existing top level of concrete before continuing placing concrete.

2. **Pumped Method.** Ensure that pump lines have a minimum diameter of 4 inches and are constructed with watertight joints.

   Ensure that the discharge end remains at least 5 feet below the surface of the plastic concrete. When lifting the pump line during concreting, temporarily reduce the line pressure until the discharge end has been repositioned at a higher level in the excavation.

   If at any time during the concrete pour the pump line discharge end is removed from the fluid concrete column and discharges concrete above the rising concrete level, consider the shaft defective. In such case, remove the reinforcement cage and concrete, complete any necessary sidewall removal directed by the RE, and replace the shaft.

Ensure that waste concrete overflows the full top circumference of the casing evenly. Waste concrete is the top 24 inches of the initial concrete placed, plus the height of 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. Continue placing concrete until the waste concrete is pushed upward and ejected completely out of the top of the casing and wasted; or, place an additional 24 inches of concrete above the planned shaft top level and allow to cure in place for removal later. Remove waste concrete at the top of the shaft to maintain a uniform appearance and to meet the specified dimensions of the shaft.

Do not channel or bleed off waste concrete using notches, holes, or cuts in the casing top. The Contractor may remove or pump out plastic concrete in the casing that is above the top elevation of the drilled shaft after ejecting waste concrete to the top elevation.

N. **Approval.** Compare the computed theoretical volume of the excavation with the actual volume of concrete placed, and create a plot of depth versus volume. Provide results to

the RE.

After placing the concrete, ensure that the top of the reinforcement steel cage is within −3 inches and +6 inches of the Plan elevation. Ensure that the top elevation of the completed drilled shaft is within −3 inches and +1 inch of the Plan elevation.

The RE may reject drilled shafts because of damage; failure to advance through; mislocation, misalignment, or failure to install the drilled shaft to the proper bearing stratum; or results of CSL testing indicating defects.

For each rejected drilled shaft, submit to the RE for approval a plan showing how to correct the problem and prevent its reoccurrence. Repair, augment, or replace the drilled shaft. If the RE rejects a drilled shaft, the Contractor shall cease the construction of all other drilled shafts until the Contractor demonstrates the ability to construct an approved drilled shaft.

Within 10 days after completing the installation of all drilled shafts, and before removing the drilled shaft installation equipment from the Project Limits, provide the RE with a plan certified by a land surveyor registered in the State of New Jersey showing the as-installed location of drilled shafts. The RE will analyze the total loads on individual drilled shafts based on the survey data. If the load on any drilled shaft exceeds 10 percent of the specified load capacity, correct the drilled shaft as directed by the RE. The corrections may include installation of additional drilled shafts.

Do not place substructure concrete on a drilled shaft until the concrete in the shaft reaches a minimum of 80 percent of the required 28-day compressive strength and until all CSL test results are approved and the CSL tubes have been dewatered and grouted.

503.04 MEASUREMENT AND PAYMENT

The Department will measure and make payment for Items as follows:

Item	Pay Unit
FURNISHING DRILLED SHAFT EQUIPMENT	LUMP SUM
DEMONSTRATION DRILLED SHAFT	LINEAR FOOT
LOAD TEST	UNIT
CROSSHOLE SONIC LOGGING	UNIT
SHAFT CORING	LINEAR FOOT
DRILLED SHAFT IN SOIL ___" DIAMETER	LINEAR FOOT

DRILLED SHAFT IN ROCK ___" DIAMETER	LINEAR FOOT
OBSTRUCTION	LINEAR FOOT
TOMOGRAPHY	UNIT

Additional Reference Material

Item Number List

The Department will make payment for each LOAD TEST completed and accepted.

The Department will not include payment for tomography under CROSSHOLE SONIC LOGGING. If the RE directs tomography, the Department will make payment for the number of 3-D evaluations performed and accepted under TOMOGRAPHY.

The Department will make payment under SHAFT CORING if the drilled core confirms that the shaft is acceptable. The Department will not make payment for shaft coring if the core confirms that there is a defect.

The Department will make payment for 60 percent of the lump sum price bid for FURNISHING DRILLED SHAFT EQUIPMENT when the equipment necessary for drilling shafts is furnished and drilling of shafts has began. The Department will make payment for the remaining 40 percent when all shafts have been drilled and all shaft concrete has been placed to the top of the shafts.

The Department will not include payment for removal of obstructions under DRILLED SHAFT IN SOIL. If an obstruction is encountered, the Department will make payment for removal of the obstruction under OBSTRUCTION.

The Department will make payment for sampling and analysis for regulated waste, including solids from dewatered slurry, under SOIL SAMPLING AND ANALYSES, REGULATED as specified in 202.04.

The Department will make payment for off-site transport and disposal and recycling of regulated waste or hazardous waste, including solids from dewatered slurry, under DISPOSAL OF REGULATED MATERIAL or DISPOSAL OF REGULATED MATERIAL, HAZARDOUS as specified in 202.04.