New Jersey Department of Transportation
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Baseline Document Change Announcement

ANNOUNCEMENT: BDC15S-13

DATE: September 22, 2016

SUBJECT: Drilled Shaft Foundations related changes
- **Revision to Section 503 of the *2007 Standard Specifications for Road and Bridge Construction*.**

Section 503-Drilled Shaft Foundations of *the 2007 Standard Specifications* has been revised to the following after a rigorous research on the subject.

The following revisions have been incorporated into the Standard Input SI2007 as of September 22, 2016.

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 (SCC)	903.06.01
Grout.	903.08.02
Reinforcement Steel	905.01.01
Drilled Shaft Casing	906.03
Steel Tube	906.08
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.

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 503.02.01-1:

Table 503.02.01-1 – 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.

503.02.02 Equipment

Provide equipment as specified:

Concrete Batching Plant 1010.01
Concrete Trucks 1010.02

Provide Crosshole Sonic Logging (CSL) test equipment as per ASTM D6760.

503.03 CONSTRUCTION

503.03.01 Furnishing Drilled Shaft Equipment

Ensure that equipment does not introduce uncontrolled exhaust fumes into the surrounding areas, or other occupied areas adjacent to the work site. Use crane and drilling equipment that is fitted with their own separate exhaust systems to adequately vent engine exhaust fumes to the atmosphere away from all 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 equal to the deepest shaft shown in the Plans, plus 15 feet or three times the shaft diameter, whichever is greater.

503.03.02 Demonstration Drilled Shaft

A. 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. A summary of the Contractor's or specialized drilled shaft subcontractor's experience and qualifications. The Contractor or subcontractor must have a minimum of 5 years experience in installation of drilled shaft foundations. The Contractor performing the work described herein must have installed shafts of similar diameter, length, capacity and working environment to those shown on the Plans.
2. The boring subcontractor and qualifications to perform the test boring at the demonstration shaft location and the boring at the production shafts when borings are required during the drilled shaft excavation.
3. The Contractor or subcontractor to install the reinforcement cage into the drilled shaft.
4. The Contractor or subcontractor to perform the placement of the drilled shaft concrete.
5. A list containing the description, type, size, capacity and number of equipment to be used.
6. Detail description of the overall construction operation sequence and the proposed sequence of shaft construction.

7. Details of planned drilled shaft excavation methods including the proposed drilling methods. Ensure the excavation method is suitable given the anticipated site.
8. 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.
9. 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.
10. Details of methods to clean and maintain the shaft excavation, including removal of loose rock and sediment from the shaft bottom.
11. Details of proposed methods to check shaft bottom cleanliness.
12. Details of steel reinforcement lifting, splicing if necessary in a hanging position, insertion and securing, including support and centralization methods.
13. Mix design of the concrete and documentation showing that the mix design meets the approved mix and strength requirements.
14. 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.
15. Methods to determine drilled shaft dimensions and the deviation from vertical for the entire depth of the drilled shaft. Details of casing removal when removal is required, including minimum concrete head in casing during removal.
16. Procedures for control and removal of spoils on land, over water, or both.
17. 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.
18. The qualification records of the testing organization, consisting of the name, title, responsibilities and specific site experience with bi-directional projects. The organization must provide proof of at least 10 successful bi-directional load tests and 3 successful lateral load tests.
19. The qualification records of the testing organization to perform the CSL test, consisting of the name, title, responsibilities and specific site experience with CSL testing.
20. Details of procedures, materials, and equipment for performing the bi-directional 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. 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 (construction, project manager, geotechnical engineering) 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 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 approve or reject the resubmission within 10 days after receipt of proposed changes of their approval or rejection.

B. Installation. Perform a demonstration drilled shaft to verify the Contractor's methods, techniques and equipment by successfully constructing a demonstration shaft.

Before demonstration shaft excavation, perform an exploratory test boring at the demonstration shaft location. Extend the test boring(s) at least 10 feet or three times the shaft diameter whichever is greater below the tip elevation of the demonstration shaft. Provide detailed information on the underlying bedrock if encountered.

Perform standard penetration test (SPT) and split-barrel sampling of soils in accordance with ASTM Standard D1586 and if rock is encountered, rock core drilling and sampling of rock for site investigation in accordance with ASTM Standard D2113. Prepare the boring logs, place the rock samples in core boxes, mark, and pack them in accordance with ASTM Standard D5079. Submit the results of the test borings, SPT tests, and photographs of each labeled core

box to the Department prior to drilled shaft excavation. If the drilled shafts are rock socketed or bearing on rock, the Department will require unconfined compression tests on a minimum of four samples in accordance with ASTM Standard D7012. Submit the test results to the Department. The Department will evaluate the rock mass strength and classify the rock using GSI and Hoek-Brown failure criterion based on AASHTO LRFD Bridge Design Specifications, 2014, Section 10.4.6.4, and determine the top of competent rock.

Install the demonstration shaft as shown on the Plans or as directed by the RE, but not less than a clear distance of three drilled shaft diameters from the closest production shaft. Excavate the demonstration shaft to the depth of the deepest and maximum diameter of the production shaft as shown on the Plans. Perform soil sampling and analyses of regulated material including solids from dewatered slurry as specified in 202.03.04. Dispose of regulated material including solids from dewatered slurry as specified in 202.03.08. Construct the demonstration shaft as specified in 503.03.07. Include CSL as specified in 503.03.04.

Load tests and evaluation of the results must be completed and approved prior to installing the production drilled shafts.

Failure to demonstrate the adequacy of methods and equipment to the RE may require the installation of an additional demonstration shaft with appropriate alterations in equipment, methods by the Contractor, or both to eliminate unsatisfactory results. An additional demonstration shaft and all testing required to demonstrate the adequacy of method or equipment will be at Contractor's expense.

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.

503.03.03 Load Test

If required, perform Axial and Lateral load tests according to ASTM D1143, D3966 or D7383.

A. Bi-Directional Load Cell Installation. Ensure that the installation and execution of the bi-directional load tests are supervised by a Professional Engineer and comply with the bi-directional load cell manufacturer recommendations, instructions and procedure manuals as approved by the Department. Ensure that the bi-directional load 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.J, to attach the bi-directional load cell. Excavate the shaft using the approved method at the location shown on the Plans. After excavating the 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 bi-directional load cell in the test shaft so that the bi-directional load cell rests firmly in the concrete. Build the bi-directional load cell into the steel reinforcing cage at a predetermined elevation approved by the Department.

After seating the bi-directional load cell assembly, place concrete in the drilled shaft as specified in 503.03.06.K. The ME will take at least 6 concrete compression test cylinders from the concrete used in the 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 bi-directional load test until 7 days after placing the concrete and the concrete achieves the specified compressive strength.

B. Load Testing and Reporting. Do not perform Axial or Lateral Load testing until CSL test results have been approved. Perform Axial Load test according to ASTM D 1143 unless otherwise specified in the Contract Documents. 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.

Take direct movement indicator measurements of the following:

1. Two Linear Variable Displacement Transducers (LVDT) vibrating wire displacement gauges, attach to each load cell to monitor the expansion and contraction of the load cell.
2. Two Linear Variable Displacement Transducers (LVDT) gauges, mount on an independent reference beam and set on opposite sides of the top of the test shaft to monitor the axial shaft displacement.
3. Vibrating wire strain gauges, placed in pairs on opposite sides of the reinforcement cage at elevations shown on the Plans.

Limit the deflection of the cage to a maximum of 2 feet between pick points while lifting the cage from the horizontal position to vertical. Provide additional support, bracing, strong backs, etc. to maintain the deflection within the specified tolerance.

Apply loads in increments of 5 percent of the maximum test load as shown on the Plans. The maximum test load is limited to the maximum axial resistance of the shaft above or below the cell or the maximum capacity of the cell or the maximum expansion of the bi-directional load cell, whichever comes first.

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, 4.0 & 8.0 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 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 bi-directional (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 final report of the load test results to the RE within 10 days of completing the test.

Ensure that the report includes, but is not limited to, the following:

1. Test shaft identification and location
2. Date(s) of testing
3. Description of the test shaft details, instrumentation and test procedures
4. Tables presenting all instrumentation data
5. Plots of load versus displacement (up and down) for each load cell level and for each stage of the test
6. Plots of load along the length of the drilled shaft determined from the strain gauge data for at least ten applied load increments
7. Summary of unit side resistance along the drilled shaft and end bearing resistance
8. Plots of creep displacement for each load increment
9. Plot of equivalent top-of-shaft displacement for the test shaft, developed from the load test data

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 bi-directional cell and annular space around the outside of the bi-directional 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

Perform the Non-Destructive Integrity Crosshole Sonic Logging (CSL) testing on completed shafts including rock socket in accordance with ASTM D 6760 (Standard Test Method for Integrity Testing of Concrete Deep Foundations by Ultrasonic Crosshole Testing).

Begin CSL on demonstration and all production drilled shafts 72 hours after placing concrete in the shaft. RE may specify a longer minimum time if concrete mix designs or other factors results in slower setting concrete. Ensure that the testing is completed within 20 days after placing concrete.

The number of access tubes is provided in the drilled shaft detail in the contract Plans.

A. Installation. Ensure the tubes are 1.610 to 2.067 inch inside diameter schedule 40 steel pipe. Ensure that the CSL tubes are watertight and have a round, regular, internal diameter free of defects or obstructions, including at tube joints, to allow the free, unobstructed passage of 1.3-inch diameter source and receiver probes. Ensure the tubes are free from corrosion with clean internal and external faces to ensure passage of the probes and a good bond between concrete and the tubes.

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 or as shown in the contract Plans. 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 potable 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.

Grout the access tube after the final acceptance of the drilled shaft.

B. CSL Testing and Reporting. Perform the CSL tests between all of the possible pairs of tubes in the drilled shaft concrete. Perform the CSL tests with the source and receiver probes in the same horizontal plane, unless the RE directs that the defect is evaluated with the source and receiver probes in different horizontal plane. 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.

Provide the RE the preliminary results of the testing on site prior to the CSL Consultant leaving the site. Submit a detailed CSL test report and test data signed and sealed by a Professional Engineer to the RE within seven days, which includes recommendations as to the acceptability, unacceptability, soundness and further evaluation of the drilled shaft.

In addition to the report requirements in ASTM D 6760, the CSL report needs to include, but not be limited to, the following:

1. Project Identification and Date of Testing.
2. Description of the testing apparatus unit and probes.
3. Name of the person responsible for the validity of the test report.
4. A table and schematic showing shafts tested with accurate identification of CSL tube coordinates and their top elevation.
5. Number of days between concrete placement and CSL testing.
6. The Data Logs: Include XY plots of Velocity, First Arrival Time (FAT) and signal strength. The signal strength needs to be expressed in units of decibels (dB).
7. An evaluation of defect zones.

Evaluation of the CSL Tests will be based on the following table:

Table 503.03.03-1 – Concrete Condition Rating Criteria

Concrete condition Rating	Velocity reduction VR(%)	Signal distortion/Strength	Indicative conditions
Good (G)	0 to 10	none/normal energy reduction ≤ 6 dB	Acceptable quality concrete
Questionable (Q)	10 to 20	Minor/lower energy reduction 6.1 to 9 dB	Minor contamination, intrusion, and/or poor quality concrete

Poor/defect (P/D)	>20	Severe/much lower energy reduction > 9 dB	contamination, intrusion, and/or poor quality concrete
No Signal (NS)	No Signal	None	Intrusion or severe defect: could also be caused by tube debonding
Water (W)	≈ 60	Severe/much lower energy reduction ≥12 dB	Water intrusion or water-filled gravel intrusion with few or no fines

C. Evaluation of the CSL Test Results. The Department will evaluate the CSL test results and determine whether or not the drilled shaft construction is acceptable. If the RE determines that the drilled shaft is acceptable, dewater and grout the CSL tubes. Use the grout with the same strength or higher than the strength of the concrete used in the original drilled shaft.

If the tests indicate potential defects, the RE may direct the Contractor to perform additional tests for further evaluation.

D. Further Evaluation. Perform Tomography, Shaft Coring or other investigated methods as directed by the RE for further evaluation. Submit a report signed and sealed by a Professional Engineer registered in the State of New Jersey providing the results of further evaluation and recommendations to accept or repair the shaft within 14 days. The report must contain recommendations for modification of construction procedures to prevent defects for subsequent shaft installation.

E. Corrective Measures. If the Department determines that the drilled shaft is unacceptable, submit working drawings for approval of proposing corrective measures. Do not begin corrective measures until the Department approves the working drawings. Repair all detected defects as per working drawings and conduct post repair integrity testing using CSL tests and 2-D and 3-D Tomography tests. Submit test results to RE within five days of tests completion for approval. The Department will not pay for these additional tests or repairs or provide an increase in contract time.

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.

503.03.05 Tomography

Use the same equipment and access tubes as the CSL method. Submit the Tomography analysis results to RE for review. Provide the two dimensional (2-D) horizontal and vertical slices and three dimensional (3-D) tomographs for the entire shaft between the respective tube pairs. Present these images in color and coded to identify the variations in sonic velocity. Include the complete discussion of the Tomography tests results in the report.

503.03.06 Shaft Coring

If the Department determines the drilled shafts are unacceptable based on CSL test results or CSL test results and tomographic analyses, or observed problems during drilled shaft construction, the RE will direct the Contractor to core the drilled shaft concrete to obtain samples in the area of the possible defects for further evaluation of accepting, repairing or replacing the drilled shaft. The Department will determine the number, location and depth of cores required. Ensure the concrete core samples are obtained in accordance with ASTM D2113. Drill cores at a diameter between 2-4 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. Perform strength test on core samples that exhibit questionable concrete as determine by Department.

503.03.07 Constructing Drilled Shafts

A. Installation Plan. Submit an installation plan, as specified in 503.03.02. Do not begin constructing drilled shafts until the RE approves the plan.

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.

B. Alignment and Tolerances. For bridge foundations, ensure that the center axis of the poured shaft at the top of the drilled shaft or mudline, whichever is lower, is within the following tolerances:

Drilled Shaft Diameter	Tolerance
≤ 2’-0”	3”
> 2’-0” < 5’-0”	4”

≥ 5'-0"	6"

During construction, periodically, check the verticality of the excavation by holding a 4-feet level on the Kelly bar or other suitable method. Ensure that the vertical alignment of a shaft excavation in soil does not vary from the alignment shown in the Plans by more than 1.5% of the shaft length. Ensure that the vertical alignment of the shaft excavation in rock does not vary from the alignment shown in the Plans by more than 2.0% of the shaft length.

For bridge foundations, after placing all the concrete, ensure that the top of the reinforcing steel cage is no more than 6 inches above and no more than 3 inches below the plan position.

Recommended concrete cover to reinforcing steel:

Drilled Shaft Diameter	Minimum Concrete Cover
≤ 3'-0"	3"
> 3'-0" < 5'-0"	4"
≥ 5'-0"	6"

Ensure that the reinforcing cage is concentric with the shaft within a tolerance of 1 inch.

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 at least the following:

1. Name of the inspector, date, time and names of changes in the inspector.
2. Identification number of each shaft.
3. Location and surface elevation at each shaft.
4. Description and approximate top and bottom elevation of each soil or rock material encountered during shaft excavation.
5. Elevations at which seepage or groundwater flow are encountered, and remarks.
6. The type and dimension of tools and equipment used for the excavation.
7. Changes in the type of tools and equipment used for excavation.
8. Type of drilling fluid used during the shaft excavation, if used.
9. Problems that are encountered during the shaft excavation.
10. Elevation changes in drilled shaft diameter.
11. Method used for bottom of the shaft cleaning.
12. Final bottom elevation of the shaft.

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 all 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 503.03.07.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 over ream 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.

Drilling tools lost in the excavation will not be considered as obstructions. 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. When downsizing of permanent casing is required, do not overlap more than 6 feet of casing.

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, submit details of the proposed casing method in the installation plan (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, 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.

If splices are needed, make splices for steel casing by full penetration butt welding in the entire cross section as per AASHTO/AWS D1.1 and as shown on the contract 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.

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.

Perform soil sampling and analyses of regulated material including solids from dewatered slurry as specified in 202.03.04. Dispose of regulated material including solids from dewatered slurry as specified in 202.03.08

1. **Mineral Slurry.** During shaft excavation, premix mineral slurry with water and allow time for hydration according to the manufacturer's recommendations. 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 all points in the borehole at the time the slurry is introduced.

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 test reports are signed, and provide them to the RE on completion of each drilled shaft.

H. Rock Socketing. If subsurface exploration is required, core drill and obtain samples of rock in accordance with ASTM Standard D2113. Prepare the boring logs and place the rock samples in core boxes, mark and pack them in accordance with ASTM Standard D5079. Submit the results of the test borings and photographs of each labeled core box to the Department prior to Drilled Shaft excavation. Perform Unconfined Compressive Strength test on a minimum of four samples retrieved from each boring. Submit the results of Unconfined Compression test results. The Department will evaluate the Rock Mass Strength and classify the rock with GSI and Hoek-Brown failure criterion based on AASHTO LRFD Bridge Design Specifications, 2014.

If the top surface of the sound rock is found to be inclined across the width of the shaft, immediately notify the RE.

Prepare rock socket for concrete placement by roughening with drilling tools or by overreaming. 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.

I. 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 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, miniature drilled shaft inspection device (mini-SID), tape with weight, or other methods approved by the RE. After final cleaning, determine the dimensions, depth, and alignment as directed by the RE. For uncased drilled shafts, determine shaft dimensions, depth and alignment with a sonar caliper. Inspect the bottom of each shaft including demonstration shaft before and after placing the rebar cage in the drilled shaft. If the cleanliness of the excavation does not meet the requirements, remove the rebar cage and clean until the above requirements are satisfied.

J. Constructing Reinforcement Steel Cages. Completely assemble and place the reinforcement steel cage, consisting of longitudinal and transverse bars, ties, cage stiffeners, spacers, centralizers, and other necessary appurtenances as a unit shown on the Plans immediately after the excavation is inspected and approved and immediately prior to concrete placement.

Use concrete spacers or other approved noncorrosive spacing devices at sufficient vertical intervals, near the bottom, and at intervals not exceeding 10 feet up the shaft, to ensure concentric location of the cage within the shaft. If the size of the spacers is not shown on the Plans, provide spacers that will create a minimum 3-inch annular space. Ensure that flat or crescent shaped centralizers ("sleds") are not used in an uncased shaft.

Provide reinforcing cage bottom support to ensure that the bottom of the cage is maintained at the specified distance above the base. Use approved non corrosive devices such as cylindrical concrete feet, mortar or plastic chairs as the bottom supports.

K. Concrete Placement. Place concrete according to the limitations specified in 504.03.02.C. Place the concrete within 24 hours after completing all excavation, cleaning the shaft bottom, inspecting and finding it satisfactory. Place concrete immediately after placing reinforcing steel cage and inspecting and finding it satisfactory. Continuously, place the concrete from the bottom of the shaft excavation to the top elevation of the shaft.

L. Time Limitations. Ensure the concrete placement in the shaft 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 be as specified in Table 903.03.06-2 during the entire time of concrete placement.

In cases when Self-Consolidated concrete is used, the RE may allow the concrete placement time to exceed 2 hours if the Contractor demonstrates that the slump flow of the Self Consolidated concrete will be as specified in Section 903.06.01B.

M. Concrete Placement Methods. Place the concrete using tremie pipe method or pump method from the bottom of the excavation. Do not allow the concrete placement by free fall method.

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 6 inches or if the downward displacement exceeds 3 inches, 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 surface of the tremie is clean and smooth to minimize drag on the concrete flow during concrete placement. Ensure that the outside surface of the tremie is smooth to avoid entanglement with the reinforcement cage. 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 tremie tubes are watertight to prevent inflow of slurry during concrete placement.

   Do not begin placing concrete under the drilling fluid (water, slurry or other fluids) until the tremie is placed to the shaft base elevation. In wet excavation and with a closed tremie, the Contractor may seal the bottom of the tremie pipe with a sacrificial cover plate. In closed end tremie, ensure that the discharge end of tremie (valves or bottom cover plate) is within 6 to 12 inches of the bottom of the concrete placement when the concrete discharge begins. For open tremie, the Contractor may use a traveling plug to act as a separator in between the drilling fluid and concrete in order to prevent mixing as the concrete travels down the tremie pipe. Remove plugs from the excavation or construct them using a material that will not cause a defect in the shaft if not removed. Ensure that the plug is not so compressible that it fails to perform its function as a separation within the tremie pipe under the anticipated hydrostatic pressure. 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 10 feet in concrete at all times after starting the flow of concrete. Use a weighted tape and a marked tremie pipe to monitor whether tremie is at least 10 feet in the concrete all the time. However, excessive embedment of the tremie into the concrete can cause the reinforcing cage to start to lift along with the rising column of concrete. Maintain a continuous flow of the concrete at a positive pressure differential to prevent water or slurry intrusion into the shaft concrete. Maintain the continuous flow of concrete until the work is completed.

   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.

2. **Pumped Method.** Concrete pumps and lines are used for concrete placement by either the wet or dry construction method. Ensure that the pump lines in the shaft are typically a rigid steel pipe, have a minimum diameter of 4 inches and are constructed with watertight joints. Ensure that the pump line is immersed at least 10 feet in concrete as with after starting the flow of 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 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 necessary sidewall removal directed by the RE, and replace the shaft.

   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.

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

N. Drilled Shaft top preparation during the completion of concrete placement. 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 consider the top-most concrete placed in the shaft as waste concrete and either:

1. Push upward and eject completely out of the top of the casing and waste as final concrete is placed. Do not channel or bleed off waste concrete using notches, holes, or cuts in the casing top. The Contractor may remove or pump out fresh concrete in the casing at a level above the Plan shaft top level after ejecting all waste concrete to the Plan top elevation while still plastic by methods and equipment approved by the Department or allow to cure in place for removal later.

2. Pump upward to a level at least 2 feet clear distance above the Plan shaft top level and allow to cure in place to remove later.

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 all additional amount necessary to produce full strength, non-segregated concrete at the Plan shaft top level.

Commence the final shaft top preparation only once the drilled shaft concrete obtains an average unconfined compression strength of at least 2500 psi, or, in lieu of concrete strength testing, after seven full days from completion of concrete placement. Final top preparation consist of:

1. Cutting off extra permanent casing above the top of casing Plan elevation
2. Cutting off cured over-pour concrete to the Plan shaft top elevation by approved methods
3. Verification by the RE that the exposed concrete consists of full strength concrete with typical, non-segregated mortar and aggregate distribution
4. Approved non-destructive strength testing where required by the RE to verify that the concrete has obtained full design strength

O. 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 elevation of the reinforcement steel cage is within −3 inches and +6 inches of the Contract Plan elevation. Ensure that the top elevation of the completed drilled shaft is within −3 inches and +1 inch of the Contract 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.

If the CSL records indicate any anomolies, the RE may require further evaluation to confirm the location of the defect. The RE may also require shaft coring, testing of core samples or excavation of the shaft to verify shaft conditions. If a defect is confirmed, with further evaluation (Tomography, shaft coring, testing of core samples or excavation), the Department will not pay for costs including shaft coring, testing of core samples, remediation, or grouting.

If no defect is encountered, the Department will pay for all shaft coring, testing of core samples and excavation costs, including grouting all core holes. The coring and grouting of core holes will be paid for at the Contract bid price per linear foot for coring of shafts including grouting core holes.

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. To mitigate or remedy rejected drill shafts, the Contractor may be required to provide additional drilled shafts or supplement drilled shafts to meet specified requirements at no cost to the Department. 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 each 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.

503.03.08 Obstructions Removal

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 obstruction cannot be removed 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.

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

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 begun. 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 make payment for sampling and analysis for regulated waste under DEMONSTRATION DRILLED SHAFT, DRILLED SHAFT IN SOIL or DRILLED SHAFT IN ROCK.

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 not make payment for off-site transport and disposal and recycling of regulated waste or hazardous waste, including solids from dewatered slurry, under DEMONSTRATION DRILLED SHAFT, DRILLED SHAFT IN SOIL or DRILLED SHAFT IN ROCK. 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.

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 REMOVAL.

Implementation Code R (ROUTINE)

Changes must be implemented in all applicable Department projects scheduled for Final Design Submission at least one month after the date of the BDC announcement. This will allow designers to make necessary plan, specifications, and estimate/proposal changes without requiring the need for an addenda or postponement of advertisement or receipt of bids.

Recommended By:

ORIGINAL SIGNED

Approved By:

ORIGINAL SIGNED

Paul F. Schneider
Acting Director
Capital Program Support

Eli D. Lambert III, P.E.
Assistant Commissioner
Capital Program Management

PS: KS: HP
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