

ITEM 551.9949NN17 - DRILLED SHAFTS

ITEM 551.9950NN17 - DRILLED SHAFTS (LOW OVERHEAD CLEARANCE)

ITEM 551.98020017 - TRIAL SHAFTS

DESCRIPTION

A. General. This work shall consist of furnishing the materials and installing drilled shafts at the locations, dimensions, and batters shown on the contract plans or where ordered by the Engineer and approved by the Deputy Chief Engineer Structures (DCES). This work includes excavating shafts, disposing of all excavated material and drilling mud, placing steel reinforcement, and placing concrete as detailed.

The intent of this work is for the Contractor or subcontractor to provide reinforced concrete shafts in cylindrical excavated holes which extend a sufficient depth into the soil and/or rock to support the structure and all externally applied loads for which it was designed.

The Contractor or subcontractor performing this work must have had prior experience installing drilled shafts, as described in this specification.

B. Definitions. Definitions that apply within this specification are:

Contractor. The contractor or subcontractor performing the work described in this specification.

Casing (Shell). A steel shell used to construct the drilled shaft. The casing can help advance the hole, and supports the sides of the hole. Casing can be permanent, interim or temporary.

Casing Method. A method of shaft construction, consisting of advancing and cleaning a cased hole, placing the reinforcing cage, and concreting the shaft while extracting temporary casing (if used).

Drilling Mud. A slurry made using bentonite or polymers (see Slurry).

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

Dry Construction Method. A method of shaft construction consisting of drilling the shaft, removing water and material from the excavation, placing the reinforcing cage, and concreting the shaft in a relatively dry condition.

Interim Casing. A casing that acts as a form, but remains in place permanently. It is not designed to carry structural loads.

Permanent Casing. A casing that is designed to carry structural loads. It acts as a form and remains in place permanently.

Quality Assurance. A test or procedure that acts to verify the quality of the work or product. Quality Assurance procedures would include static load testing, Osterberg cell testing, coring, cross hole sonic logging, and other non-destructive testing.

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Rock. Rock is identified in the boring logs. Rock may also be defined at the shaft installation site by a Departmental Engineering Geologist.

Seat. The act of placing the tip of a casing in intimate contact on rock for its entire circumference.

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

Surface Casing. Temporary casing installed to prevent sloughing of the surrounding soil near the surface of the shaft excavation.

Temporary Casing. A casing that serves its function during construction of the drilled shafts. It serves no permanent structural function, and is extracted during concreting.

Top of Socket. The highest location of the rock socket that is capable of resisting axial and lateral design loads. At any given location, the top of socket elevation is usually below the top of rock elevation. This distance depends on the type and quality of the rock, and the Contractors drilling methods and equipment.

Tremie. A method to place concrete under water. Refer to Section 555 *Structural Concrete*.

Trial Shaft. A hole for a drilled shaft constructed on the project site, but outside the proposed footing limits. It is not to be incorporated into a structure or foundation. A trial shaft is constructed prior to installing production drilled shafts, according to the methods detailed in the Contractor's submittals. Its function is to verify the proposed excavation methods, and permit the Inspectors to become familiar with the excavation procedure. Upon inspection and acceptance, the trial shaft is backfilled with unreinforced concrete.

Wet Construction Method. A method of shaft construction in which slurry is used to maintain stability of the hole while advancing the excavation to the final depth, placing the reinforcing cage, and concreting the shaft.

MATERIALS

Refer to the contract plans to determine which of the following materials will be required.

For all steel remaining as a permanent part of the work, all Buy America provisions shall apply.

A. Permanent Casing. Provide continuous permanent casing conforming to the limits shown on the contract plans.

Provide material conforming to the requirements of ASTM A252 Grade 2, unless specified otherwise in the contract plans. Furnish full length shells, consistent with requirements shown in

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the contract documents. Unless otherwise specified in the contract documents, use of spiral welded casing is not permitted.

If needed, equip casing with an appropriate casing shoe to enable installation of casing to the elevations shown on the contract plans.

B. Interim Casing. Provide interim casing capable of withstanding all handling and installation stresses. If needed, equip casing with an appropriate casing shoe to enable installation of casing to the depths necessary to construct the drilled shaft to the elevations shown on the contract plans.

C. Temporary Casing. Provide temporary casing capable of withstanding all handling and installation and extraction stresses. If needed, equip casing with an appropriate casing shoe to enable installation of casing to the depths necessary to construct the drilled shaft to the elevations shown on the contract plans.

D. Reinforcing Steel. Provide bar reinforcement meeting the requirements of §709-01 *Bar Reinforcement, Grade 60* or ASTM A615 *Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement*.

E. Concrete. Provide concrete conforming to the requirements of Section 501 Portland Cement Concrete - General, Class GG, as presented in Table 501-3 *Concrete Mixtures*. The Contractor is allowed the option of using admixtures to increase the slump to a maximum of 9 inches, provided all other mixture requirements set forth in Table 503-1 are achieved.

F. Centralizers. Provide centralizers for properly aligning the steel reinforcement, made of a material that is not detrimental to the reinforcement or the concrete. The type of centralizer utilized must be approved by the DCES.

G. Rebar Cage Feet. Provide cylindrical feet to support the rebar cage at the proper elevation, made of a material that is not detrimental to the reinforcement or concrete. The type of feet utilized must be approved by the DCES.

H. Protective Coating for Permanent Casing. Provide a Coal Tar Epoxy-Polyimide Coating meeting the requirements of, and apply it in accordance with SSPC-PS 11.01: Black (or Dark Red) Coal Tar Polyimide Painting System. Apply the coating between the limits shown on the contract plans.

I. Mineral Slurry. Provide a mineral (bentonite) slurry that will remain in suspension, and with sufficient viscosity and gel characteristics to transport excavated material to a suitable screening system. Provide a slurry with the percentage and specific gravity of the material used to make the suspension sufficient to maintain the stability of the excavation and to allow proper concrete placement.

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

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Range of Values (68°F)			
Property (Units)	Time of Slurry Introduction	Time of Concreting (In hole)	Test Method
Density (lb/ft ³)	64.3 to 69.1	64.3 to 75.0	Density Balance
Viscosity (seconds/quart)	28 to 45	28 to 45	Marsh Cone
pH	8 to 11	8 to 11	pH paper or meter

Increase density range values by 2 pcf in salt water.

Desand the slurry so that the sand content does not exceed 4 percent (by volume) prior to concrete placement as determined by the American Petroleum Institute sand content test.

J. Polymer Slurry. Provide a polymer slurry with sufficient viscosity and gel characteristics to hold the hole open, and transport excavated material to a suitable screening system.

Polymer slurry may be made from PHPA (emulsified), vinyl (dry), or natural polymers.

Desand the polymer slurry so that the sand content is less than 1 percent (by volume) prior to concrete placement, as determined by the American Petroleum Institute sand content test.

K. Water. Provide water conforming to the requirements of §712-01 *Water*, except with a pH conforming to the slurry requirements listed above.

CONSTRUCTION DETAILS

A. Prior Experience. Submit proof and details of the following:

1. Two projects in the past 5 years where the Contractor or subcontractor performing the work has successfully installed drilled shafts similar to the size and type on this project.
2. The foreman for this work having supervised the successful installation of drilled shafts on at least two projects in the last 2 years.
3. The drill operators having had at least one year of experience installing drilled shafts with similar diameters and lengths, and in similar conditions.

Include details describing the equipment and methods used, any difficulties encountered and how they were overcome, and the results of any testing performed. Include the name and telephone number of someone for each project cited who can be contacted as a reference. Submit this information to the DCES for review, evaluation, and approval prior to submitting detailed

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information as stated in this specification under C. Submittals. The DCES will render a decision within 15 working days after the receipt of all information. A Contractor or subcontractor will not be permitted to install drilled shafts without this approval.

All approvals are subject to trial and satisfactory field performance. Departmental approval does not relieve the Contractor or subcontractor of his responsibility to satisfactorily complete the work detailed in the contract documents.

B. General. Provide the equipment and use procedures necessary to install drilled shafts at the locations and to the elevations shown on the contract plans, or as approved by the DCES.

Prior to preparing submittals, fully examine the existing site conditions and subsurface exploration logs.

The construction methods selected are directly related to the method of load transfer assumed in the project design. The type of drilling method, presence of permanent or interim casing, and clean out procedure all affect the drilled shaft load transfer behavior in skin friction and end bearing. Construct the drilled shafts using construction methods consistent with the load transfer mechanism shown on the contract plans.

C. Submittals. Submit the proposed procedure and equipment for installing drilled shafts to the DCES for review and approval prior to commencing the work. The DCES will render a decision within 15 working days, measured from the date of receipt of all pertinent information. The submittal should include, but not be limited to, the following information:

1. Method describing how the Contractor will progress through obstructions and rock.
2. Details and method describing how the Contractor will keep the hole for the drilled shaft open.
3. Drawings showing and details describing the proposed sequence of drilled shaft installation. Include the sequence for each shaft, the overall construction sequence, and the sequence of shaft construction in bents or groups.
4. Information describing the type of equipment to be used, including drill rig, cranes, drilling tools, final cleaning equipment, desanding equipment, slurry pumps, sampling equipment, tremie or concrete pumps, casing (including casing dimensions, material and splice details), etc.
5. Proposed method for cleaning out the shaft excavations. Include a description of how the Contractor will perform spoil removal and disposal.
6. Documentation that shows that the Contractor, Driller, and Foreman have the requisite prior experience in installing drilled shafts. Include the name and telephone number of someone for each project cited who can be contacted as a reference.
7. Shaft excavation methods, and final shaft dimensions.

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8. If slurry is to be used, indicate the method proposed to mix, circulate, and desand the slurry. Include methods of slurry disposal in the submittal.
9. Method of reinforcement placement, including support and centralization type and methods.
10. Details and method of concrete placement, curing, and protection.
11. If the concrete mix is modified (i.e., retarders), include the new mix design, and test results of cylinder breaks from an independent laboratory. Also, include test results that demonstrate a slump loss versus time relationship.
12. A description and details of the slurry sampling tool to be used. Provide a tool capable of taking a slurry sample at a specific depth, without being contaminated by slurry from another depth.
13. When slurry is used, include an alternate procedure to be used which will secure the shaft in the event of slurry loss.
14. A description of the type of feet to be used to support the rebar cage in the drilled shaft.
15. An emergency construction joint procedure, to be used in the event when concrete placement for the drilled shaft is unexpectedly interrupted.
16. A procedure for filling voids between permanent or interim casing and the soil.
17. A description of equipment and methods to be used for drilled shaft inspection. The Inspector will use these methods and equipment to inspect the drilled shafts. The inspection program must be thorough enough to assure the Department that each drilled shaft meets the requirements contained in this specification.

Do not begin work until the DCES has issued all approvals.

D. Construction Tolerances

1. The allowable tolerance from plan location is 3 inches at the top of shaft elevation. Measure the as-drilled center of shaft using reference stakes offset from the shaft excavation.
2. The allowable tolerance from the required verticality is 2%. For battered shafts, the allowable tolerance from the required batter is 3%. This tolerance applies for the total length of shaft.
3. Cutoff elevation tolerance is plus 1 inch to minus 3 inches from the top of shaft elevation shown in the contract plans.
4. Rebar stick up elevation tolerance, after all shaft concrete has been placed, is plus or minus 2 inches from the stick up elevation shown in the contract plans.

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5. The bottom of the shaft excavation is perpendicular to the axis of the shaft, within a tolerance of $\frac{3}{4}$ inch per foot of shaft diameter.
6. Tolerances for the diameter are as follows:
 - a. The minimum diameter of the drilled shaft is not more than 1 inch less than the diameter shown on the plans.
 - b. The maximum shaft diameter is the diameter shown on the plans plus 6 inches. Verify the diameter for the entire length of the shaft using devices constructed of a rigid rod with four 90° offset rods.

Drilled shaft excavations and completed shafts not constructed within the required tolerances are unacceptable. Submit written correction procedures to the DCES through the Engineer for approval prior to correcting the deficiencies. The Contractor is responsible for correcting all unacceptable shaft excavations and completed shafts to the satisfaction of the Engineer at no cost to the State.

E. Drilling and Excavation

1. General. When drilled shafts are to be constructed in conjunction with embankment placement, construct shafts after placement of the fill, unless otherwise shown on the contract plans.

The Contractor is responsible for reviewing all the subsurface and site information, and limitations, for the project.

2. Trial Shafts. Construct trial shaft(s) in accordance with the same methods submitted and approved for production drilled shaft installation. The purpose of the trial shaft installation is to demonstrate the adequacy of the Contractor's proposed methods and equipment for excavating the drilled shafts.

Construct trial shaft(s) in the area(s) designated on the contract plans, or as directed in writing by the Engineer. Progress the trial shaft(s) to the depth shown on the plans.

Progress the holes for the trial shaft(s) to the required elevation(s) in such a manner so as not to cause disturbance or settlement to the surrounding ground surface or adjacent structures. If any disturbance occurs, halt operations and modify the equipment and/or procedures so as not to cause any further disturbance. Submit the modified drilled shaft installation procedure, in writing, to the DCES through the Engineer. After receiving approval from the DCES, repair any damage at no cost to the State, and proceed.

During drilling or excavation of the shaft(s), make frequent checks of the plumbness, alignment, and dimensions of the shaft. Correct any deviations exceeding the allowable tolerances using a procedure approved by the Engineer.

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Clean the inside of the holes for the trial shaft(s) to the diameters and depths called for in the contract plans. Dispose of all excavated material in accordance with Section 203.

After the trial shaft(s) have been excavated, inspected, and accepted, remove any casing used and backfill the hole(s) with unreinforced concrete. Cut off the completed trial shaft(s) 2 feet below finished grade. Restore the disturbed areas in the vicinity of the trial shaft(s) as nearly as possible to their original condition.

Failure of the Contractor to demonstrate the adequacy of methods and/or equipment to the Engineer constitutes reason for the Engineer to require alterations in methods and/or equipment. Construct any additional trial shaft(s) necessary to achieve satisfactory results at no additional cost to the State, as ordered by the Engineer.

3. Drilled Shafts and Drilled Shafts (Low Overhead Clearance). Excavate the holes and dispose of all excavated material for production drilled shafts using the same requirements, methods, procedures, and equipment used to satisfactorily excavate trial shaft(s), if trial shafts were used. Otherwise, use the same methods approved by the DCES. Do not alter equipment and/or methods without written permission by the DCES.

Where drilled shafts are located in open water areas, extend exterior casings (temporary, interim or permanent) 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 exterior casing in such a manner so as to produce a positive seal at the bottom of the casing and prevent piping of water or other materials into or from the shaft excavation.

Do not keep mineral slurry in the holes while drilling rock sockets, as it has a detrimental effect on the concrete-to-rock bond.

4. Dry Construction Method. This method will only be permitted at sites where all of the following apply:

- a. The groundwater table and site conditions are suitable to permit construction of the shaft in a relatively dry excavation.
- b. Where the sides and bottom of the shaft remain stable without any caving, sloughing, or swelling.
- c. Where the sides and bottom of the shaft can be visually inspected prior to placing the rebar cage and concrete.

A “relatively dry” excavation is one where the infiltration rate does not exceed 12 inches of water in one hour. Perform all operations so that less than 2 inches of water remain at the bottom of the excavation at the time of concreting.

5. Wet Construction Method. The wet construction method may be used at sites where a dry excavation cannot be maintained for placement of the shaft concrete. This procedure

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may require cleaning the slurry, and final cleaning of the excavation by means of a bailing bucket, air lift, submersible pump, or other devices.

Maintain a minimum slurry level of 4 feet above the highest groundwater level encountered on the project.

Provide surface casings to aid shaft alignment and position, and to prevent sloughing of the top of the shaft excavation, unless it is demonstrated to the satisfaction of the Engineer that the surface casing is not required.

6. Temporary Casing Construction Method. Use this method at sites where the stability of the excavated hole and/or the effects of groundwater cannot be controlled by other means. Install temporary casing using rotating, oscillating, driving, or vibratory methods unless methods are required or limited in the contract plans. Install temporary casing in advance of the excavation to the lower limits of the casing material.

Remove temporary casing while the concrete is still workable. As the casing is withdrawn, maintain a 5 foot minimum head of fresh concrete in the casing so that all fluid trapped behind the casing is displaced upward without contaminating the shaft concrete. Extract the casing at a slow, uniform rate, with the pull in line with the axis of the casing.

7. Interim Casing Construction Method. Use this method at sites where the stability of the excavated hole and/or the effects of groundwater cannot be controlled by other means. Install interim casing using rotating, oscillating, driving, or vibratory methods unless methods are required or limited in the contract plans. If full penetration cannot be attained, the Contractor may either excavate material within the embedded portion of the casing, or excavate a pilot hole ahead of the casing until the casing reaches the desired penetration. Progress the pilot hole centered in the shaft, and no larger than one-half the diameter of the shaft.

Progress the interim casing so that the casing maintains intimate contact with the soil.

8. Permanent Casing Construction Method. This method generally consists of installing the permanent casing to a prescribed elevation prior to excavating. Install permanent casing using rotating, oscillating, driving, or vibratory methods unless methods are required or limited in the contract plans. If full penetration cannot be attained, the Contractor may either excavate material within the embedded portion of the casing, or excavate a pilot hole ahead of the casing until the casing reaches the desired penetration. Progress the pilot hole centered in the shaft, and no larger than one-half the diameter of the shaft.

Progress the permanent casing so that the casing maintains intimate contact with the soil.

9. Slurry. Pre-mix the slurry, and allow adequate time for hydration prior to introduction into the shaft excavation. Provide adequate slurry tanks when specified or required by the

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Engineer. Do not mix slurry in the hole for the drilled shaft. Slurry pits will not be allowed without written permission from the Engineer.

Provide adequate desanding equipment where required for slurry operations. Take appropriate steps to prevent slurry from “setting up” in the shaft excavation, such as agitation, circulation, and adjusting the properties of the slurry. Do not let the slurry sit unagitated for more than 4 hours. If the slurry is in the hole, unagitated for more than 4 hours, scrape the sides to remove the filter cake before proceeding with the excavation.

Perform control tests on the slurry to determine density, viscosity, and pH before and during shaft excavation to establish a consistent working pattern.

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

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

10. Excavation Inspection. Provide equipment for checking the dimensions and alignment of each shaft excavation. Determine the dimensions and alignment under the direction of the Engineer. Measure the final shaft depth after cleaning.

F. Rock Sockets. Progress rock sockets to the depth, diameter and elevations shown on the contract plans. If the top of socket elevation varies from that shown on the contract plans by more than 3 feet, notify the Engineer who will contact the DCES for a redesign.

G. Quality Assurance Equipment Installation. Install any quality assurance equipment prior to concreting the hole. This includes any pipes for crosshole sonic logging, and any other instrumentation.

H. Rebar and Concrete Placement, and Temporary Casing Removal. Place reinforcing and concrete within 2 hours after the drilled shaft has been excavated, cleaned out, inspected, and accepted by the Engineer.

Completely assemble the reinforcing steel cage, including longitudinal bars, ties, cage stiffener bars, centralizers, concrete feet, and other necessary appurtenances.

Place and center the rebar cage in the hole for the drilled shaft prior to concreting the shaft. Install centralizers at the bottom and along the axial length of the steel reinforcing at sufficient spacing to maintain proper concrete cover (minimum 3 inches), but at a spacing that does not

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exceed 10 feet. Place approved cylindrical feet (bottom supports) at the bottom of the cage to ensure that the bottom of the cage is maintained at the proper distance above the base.

Immediately prior to concreting, take depth measurements with a weighted tape. Clean out the hole if there is more than 1/2 inch of debris on the bottom for end-bearing shafts, and 2 inches of debris for side-friction shafts. If drilling mud is being used to support the hole, perform slurry contamination tests in accordance with the American Petroleum Institute's (API's) test *Standard Procedure for Field Testing Drilling Fluids*, API RP-13B. Adjust the slurry to meet contract specification requirements.

Check the elevation of the top of the rebar cage before and after placing the shaft concrete. If the rebar cage is not maintained within the specified tolerances, make corrections to the satisfaction of the Engineer. Do not construct additional shafts until the procedure has been modified, to the satisfaction of the Engineer.

For drilled shafts constructed using the Dry Construction Method, place concrete by tremie, pumping, or free-fall. When placing concrete by free-fall, direct the concrete so that it does not strike the sides of the excavation or the reinforcing cage.

For all other drilled shafts, place concrete in accordance with the requirements of §555-3.04 *Handling and Placing Concrete* and §555-3.05 *Depositing Structural Concrete Under Water* except place the concrete using the tremie method, by pumping, or by another method approved by the Engineer. Do not place concrete using free fall. Place concrete in one continuous operation to the top of the shaft.

For shafts less than 8 feet in diameter, conduct operations so that the elapsed time from the beginning of concrete placement in the shaft to the completion of placement does not exceed 2 hours, unless an approved shaft concrete retarder is used. Proceed so that the concrete mix remains in a workable plastic state throughout the 2 hour placement limit.

When the top of shaft elevation is above ground, form the portion above ground with a removable form, or with permanent casing when specified.

Temporary casings which become bound during shaft construction and cannot be practically removed are unacceptable unless the Contractor can prove to the Department's satisfaction that the casing will not adversely affect the performance of the drilled shaft. Submit a procedure for correcting this to the Engineer for approval before conducting further work on the shaft.

Do not conduct any construction operations which may cause soil movement immediately adjacent (within 5 feet) to the drilled shaft for 24 hours after completing the shaft concrete pour.

Fill any voids between permanent or interim casing and the soil with concrete at least 48 hours after concreting the shaft.

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Pumped Concrete. All provisions of §555-3.05 *Depositing Structural Concrete Under Water* shall apply.

I. Quality Assurance. Provide Quality Assurance as required on the contract plans.

In the event the Quality Assurance testing indicates voids or discontinuities in the concrete, which, as determined by the DCES, indicate that the drilled shaft is not structurally adequate, submit a written proposal for correcting the deficiencies and steps to prevent them from recurring to the Engineer for approval by the DCES. Do not continue working on the drilled shaft in question, or any other drilled shaft, until the DCES grants approval. Perform any additional QA verification work (such as full depth shaft coring) and/or corrective work necessary as a result of shaft defects at no additional cost to the State.

METHOD OF MEASUREMENT

A. Drilled Shafts and Drilled Shafts (Low Overhead Clearance). This work will be measured as the number of feet of drilled shaft furnished, installed, and accepted, measured between the cut-off elevation and the tip elevation shown on the contract plans or as changed, in writing, by the Engineer.

B. Trial Shafts. This work will be measured as the number of trial shafts installed and accepted.

BASIS OF PAYMENT

The unit price bid for each item shall include the cost of furnishing all labor, material, and any equipment necessary to complete the work not included in the applicable pay item for furnishing equipment for installing drilled shafts. This includes progressing the hole through all soil, rock, and obstructions, placing concrete and reinforcing steel in the drilled shaft, installing temporary, interim and/or permanent casing, and supplying the methods and equipment for drilled shaft inspection.

Note: The “NN” in the Pay Item denotes a serialized pay item. Refer to §101-02 *Definitions of Terms*. The State will make payment for each specified diameter of drilled shaft.

Quality Assurance, including any load testing and non-destructive testing (i.e. crosshole sonic logging), will be paid for under separate items. There will be no payment for additional quality assurance testing (i.e. coring) that is required to verify or quantify anomalies detected by the initial QA testing.

There will be no extra payment for leaving bound temporary casing, deemed acceptable to the Engineer, in place.

Include the cost for furnishing equipment to install Trial Shafts in the applicable pay item for furnishing equipment for installing drilled shafts.

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There will be no separate payment for equipment changes to install trial shafts and production drilled shafts.

Payment will be made under:

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551.98020017	Trial Shafts	Each