

**REVIEW OF NEW SPECIFICATION OR SPECIFICATION CHANGE**

503-1

**Specification Section No.:** 503

**Item:** Drilled Shafts

**Originating Office:** MAC

**By:** David Thomas

**Date Sent For Review:** 09.20.16

**Date Comments Due:** 10.18.16

**Submit response to: STANDARDS AND SPECIFICATIONS UNIT, DIVISION OF PROJECT SUPPORT  
4<sup>TH</sup> FLOOR, CDOT HEADQUARTERS**

Vote Y/N	Concurrent Reviews – Others Commenting	
	<b>Spec Committee Members:</b>	✓
	Co-Chairman: Lacey	
	Region 1: Quirk	
	Region 1: Stratton	
	Region 2: Phillips	
	Region 3: Necessary	
	Region 4: Boespflug	
	Region 5: Valentinelli	
	Project Development: Vacant	
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	Bridge: Hasan	
	Contracts & Market Analysis: Eddy	
	Materials: Schiebel	
	Traffic Engineering: Matthews	
	Maintenance: Weldon	
	FHWA: Feery	
	Attorney General: Milan	
	<b>Others:</b>	
	Colorado Contractors Assoc.: Moody	
	<b>Technical Committees:</b>	
	PDAC	
	Drainage Advisory Committee (DAC)	

The attached Draft Specification is submitted for your review and comments. If not returned by Date Comments Due, the draft specification will be considered to be approved unless the Standards and Specifications Unit of the Project Development Branch [(303) 757-9474, (303) 757-9402] is advised otherwise.

**REMARKS:**

If these proposed modifications are approved, our unit will issue these in a new standard special provision.

**REVIEWER COMMENTS:**

( ) Approved ( ) Disapproved ( ) Modified

If disapproved or modified, give reason why and show any modifications on the attached draft copy:

\_\_\_\_\_  
Name/Signature

\_\_\_\_\_  
Date



<b>COLORADO DEPARTMENT OF TRANSPORTATION</b> <b>SUBMITTAL OF NEW SPECIFICATION OR</b> <b>SPECIFICATION CHANGE</b>		Log No. (Assigned by Standards and Specifications Unit)
TO: Standards and Specifications Unit, Project Development, Suite 290		FROM: Materials Advisory Committee  (Region, Branch or Technical Committee)
SPECIFICATION SECTION NO.  503	ITEM  Drilled Caissons	Priority  Routine <input checked="" type="checkbox"/> Fast <input type="checkbox"/>
Reason for this new or changed specification:  The specification was updated to include non-destructive testing, wet construction methods, construction submittals, and quality control requirements. The changes were developed under a Materials Advisory Committee (MAC) Task Force TF 2015-02 involving the Colorado Contractors Association. The specification changes were approved by the MAC.		
New or Revised Specification:  See Attached.		

NOTE: See Procedural Directive 513.1 for a description of appropriate specification development procedures.

**SECTION 503  
DRILLED SHAFTS**

Section 503 of the Standard Specifications is hereby deleted for this project and replaced with the following:

**DESCRIPTION**

**503.01** This item of work consists of furnishing all materials, labor, tools, equipment, services and incidentals necessary to construct the drilled shafts (also referred to as drilled caissons, drilled piers, cast-in-place-drilled-holes, or cast-in-situ piles) in accordance with the Contract Documents and this Specification.

**SUBMITTALS AND MEETINGS**

**503.02 Submittals.** At least four weeks prior to the start of drilled shaft construction, the Contractor shall submit three copies of a project reference list to the Engineer for approval verifying the successful completion by the Contractor of at least three separate foundation projects within the last five years with drilled shafts of similar size (diameter and depth) and construction difficulty to those shown in the Plans in similar subsurface geotechnical conditions. A brief description of each project and the project owner's contact name and current phone number shall be included for each project listed.

(a) *Experience and Personnel.* The personnel assigned to the project shall have the following minimum experience:

- (1) On-site supervisors shall have a minimum of two years of experience in supervising construction of drilled shaft foundations of similar size (diameter and depth) and installation method to those shown in the Plans and similar geotechnical conditions to those described in the geotechnical report. The work experience shall be direct supervisory responsibility for the on-site drilled shaft construction operations. Project management level positions indirectly supervising on-site drilled shaft construction operations are not acceptable for this experience requirement.
- (2) Drill rig operators shall have a minimum one year experience in construction of drilled shaft foundations.

The Engineer may request a list identifying on-site supervisors and drill rig operators assigned to the project for review and acceptance. The list shall contain a detailed summary of each individual's experience in drilled shaft excavation operations including placement of assembled reinforcing cages and concrete in drilled shafts. The Engineer will accept or reject the Contractor's qualifications and field personnel within ten working days after receipt of the submission. Work shall not start on any drilled shaft until the Contractor's qualifications and field personnel are accepted by the Engineer. The Engineer may suspend the drilled shaft construction if the Contractor substitutes field personnel without prior acceptance by the Engineer. The Contractor shall be fully liable for the additional costs resulting from the suspension of work and no adjustments in contract time resulting from such suspension of work will be allowed.

(b) *Drilled Shaft Installation Plan.* At least four weeks prior to the start of drilled shaft construction the Contractor shall submit three copies of a Drilled Shaft Installation Plan narrative for acceptance by the Engineer. In preparing the narrative, the Contractor shall reference the available subsurface geotechnical data provided in the Contract and any geotechnical reports prepared for this project. This narrative shall provide at a minimum the following information:

- (1) Description of overall construction operation sequence and the sequence of drilled shaft construction when in groups or lines.
- (2) A list, description and capacities of proposed equipment including but not limited to cranes, drills, augers, bailing buckets, final cleaning equipment and drilling unit. As appropriate, the narrative shall describe why the equipment was selected and suitability to the anticipated site and subsurface conditions. The narrative shall include a project history of the drilling equipment demonstrating the successful use of the equipment on shafts of equal or greater size in similar subsurface geotechnical conditions.
- (3) Details of drilled shaft excavation methods, including proposed drilling methods, methods for cleanout of the bottom of the excavation hole and a disposal plan for excavated material including drilling slurry (if applicable). If appropriate this shall include a review of method suitability to the anticipated site and

subsurface geotechnical conditions including boulders and obstruction removal techniques if such are indicated in the Contract subsurface geotechnical information or Contract Documents.

- (4) Details of the methods to be used to ensure drilled shaft hole stability (i.e., prevention of caving, bottom heave, etc. using temporary casing, slurry, or other means) during excavation and concrete placement. The details shall include a review of method suitability to the anticipated site and subsurface geotechnical conditions.
  - (5) Detailed procedures for mixing, using, maintaining, and disposing of the slurry shall be provided if applicable. A detailed mix design (including all additives and their specific purpose in the slurry mix) and a discussion of its suitability to the anticipated subsurface geotechnical conditions shall also be provided for the proposed slurry.
  - (6) The submittal shall include a detailed plan for quality control of the selected slurry including property tests, test methods, and minimum and/or maximum property requirements which must be met to ensure that the slurry functions as intended for the anticipated subsurface conditions and shaft construction methods in accordance with the slurry manufacturer's recommendations and these Specifications. At a minimum, the slurry quality control plan shall include density, viscosity, pH and sand content tests.
  - (7) When casings are proposed or required, casing dimensions and detailed procedures for casing installation, removal, advancing the casing, and excavating the drilled shaft hole in accordance with subsection 503.13 (b) of this Specification shall be provided. When removing casing, detail the method to extract the casing to maintain shaft reinforcement in proper alignment and keep concrete workable during casing extraction.
  - (8) Details of concrete placement including proposed equipment and procedures for delivering concrete to the drilled shaft, placement of the concrete into the shaft, placement and raising of the tremie or pump line during placement, size of tremie and pump lines, operational procedures for pumping, and a sample uniform yield form to be used by the Contractor for plotting the volume of concrete placed versus the depth of shaft for all shaft concrete placement. Describe the method to be used to form a horizontal construction joint during concrete placement. Details of procedures to prevent loss of slurry or concrete into waterways, and other areas to be protected.
  - (9) Describe the method and materials that will be used to fill or eliminate all voids below the top of shaft between the plan shaft diameter and excavated shaft diameter, or between the shaft casing and surrounding soil if permanent casing is specified.
  - (10) Details of any required load tests including equipment, instrumentation, procedures, calibration data for test equipment, calculations and drawings.
  - (11) Details and procedures for protecting existing structures, utilities, roadways and other facilities during drilled shaft installation.
  - (12) Other information required by the Plans, specified herein, or requested by the Engineer.
- (c) *Slurry Technical Assistance.* If slurry is used to construct the drilled shafts, the Contractor shall provide or arrange for technical assistance from the slurry manufacturer as specified in Subsection 503.13 (b).5.(1) of this Specification. The Contractor shall submit three copies of the following to the Engineer:
- 1) The name and current phone number of the slurry manufacturer's technical representative assigned to the project.
  - 2) The names of the Contractor's personnel assigned to the project and trained by the slurry manufacturer's technical representative in the proper use of the slurry. The submittal shall include a signed training certification letter from the slurry manufacturer for each individual including the date of the training.

(d) *Logs of Shaft Construction.* The Contractor's Quality Control staff shall prepare inspection logs using CDOT Form 1333 – Inspector's Report of Caisson Installation documenting each shaft construction activity, including casing installation, excavation, shaft bottom inspection, reinforcement installation and concrete placement. The logs shall fully document the work performed with frequent reference to the date, time and casing/excavation elevation. In addition, the Contractor shall prepare and submit the logs documenting any subsurface investigation borings or rock core holes performed for the Contract at drilled shaft foundation locations. Records for temporary and permanent casing shall include at least the following information: identification number and location of the shaft; diameter and wall thickness of the casing; dimensions of any casing reinforcement; top and bottom elevations of the casing; method and equipment used for casing installation; any problems encountered during casing installation; and the name of the inspector.

The shaft excavation log shall contain at least the following information: identification number, location and surface elevation of the shaft; description and approximate top and bottom elevation of each soil or rock material encountered; seepage or groundwater conditions; type and dimensions of tools and equipment used, and any changes to the tools and equipment; type of drilling fluid used, if any, and the results of slurry tests; any problems encountered; elevation of any changes in the shaft diameter; method used for bottom cleaning; final bottom elevation of the shaft; and the name of the inspector.

Concrete placement records shall include at least the following information: concrete mix used; time of start and end of concrete placement; volume and start/end time for each truck load placed; concrete test results; concrete surface elevation and corresponding tremie tip elevation periodically during concrete placement; concrete yield curve (volume versus concrete elevation, actual and theoretical); and the name of the inspector.

The logs for each shaft construction activity shall be submitted to the Engineer within 24 hours of the completion of that activity. A full set of shaft inspection logs for an individual drilled shaft shall be submitted to the Engineer within 48 hours of the completion of concrete placement at the shaft.

**503.03 Meetings.** The Engineer will evaluate the Drilled Shaft Installation Plan for conformance with the Contract Plans and Specifications within ten working days after receipt of the submission. At the option of the Owner, a Shaft Installation Plan Submittal Meeting may be scheduled following review of the Contractor's initial submittal of the Plan. Those attending the Shaft Installation Plan Submittal Meeting, if held, should include the following:

- (1) The superintendent, on-site supervisors, and other Contractor personnel involved in the preparation and execution of the Drilled Shaft Installation Plan.
- (2) The Project Engineer and Owner's personnel involved with the structural, geotechnical, and construction review of the Drilled Shaft Installation Plan together with Owner's personnel who will provide inspection and oversight during the drilled shaft construction phase of project.

The Contractor shall submit any significant updates or modifications to the Drilled Shaft Installation Plan whenever such updates or modifications are proposed to the Engineer. The Engineer will evaluate the new information for conformance with the Contract Plans and Specifications within ten working days after receipt of the submission.

A shaft preconstruction meeting shall be held at least five working days prior to the Contractor beginning any shaft construction work at the site to discuss investigative boring information, construction procedures, personnel, and equipment to be used, and other elements of the accepted Shaft Installation Plan as specified in Subsection 503.02.(b) of this Specification. If slurry is used to construct the shafts, the frequency of scheduled site visits to the project site by the slurry manufacturer's representative will be discussed. Those attending shall include:

- 1) The superintendent, on site supervisors, and other key personnel identified by the Contractor as being in charge of excavating the shaft, placing the casing and slurry as applicable, placing the steel reinforcing bars, and placing the concrete. If slurry is used to construct the shafts, the slurry manufacturer's representative and a Contractor's employee trained in the use of the slurry, as identified to the Engineer in accordance with Subsection 503.04.(c).4.(1) of this Specification, shall also attend.
- 2) The Engineer, key inspection personnel, and appropriate representatives of the Owner. If the Contractor's key personnel change, or if the Contractor proposes a significant revision of the approved Drilled Shaft Installation Plan, an additional conference may be held at the request of the Engineer before any additional shaft construction operations are performed.

**503.04 Approvals.** Work shall not begin until all the required submittals have been accepted in writing by the Engineer. All procedural acceptances given by the Engineer shall be subject to trial in the field and shall not relieve the Contractor of the responsibility to satisfactorily complete the work.

**503.05 Control and Disposal of Materials.** The Contractor shall dispose of excavated material, as well as slurry and/or water removed from the shaft excavation. Collect and properly dispose offsite all slurry and water displaced during final cleaning and concrete placement. Open pits for collection of materials will not be allowed. Control all excavated material, slurry, water, and other matter so that at no time it enters or encroaches upon the adjacent travel lanes, railroad, water ways, and so forth. All environmental regulations for handling, discharge, and disposal of all construction materials shall be followed.

## MATERIALS

**503.06 Concrete.** Concrete used in the construction of drilled shafts shall be Class BZ and shall conform to the requirements of Section 601. If the concrete does not meet the requirements of Section 601, reductions shall be applied to Subsection 503.24 drilled caisson pay item. The concrete slump shall be between 6 in. and 9 in. and the coarse aggregate size shall not exceed 0.375 in. A minimum of 6 in. slump shall be required during the period equal to the anticipated pour period plus 2.0 hours. The use of retarders and mid-range water reducers is allowed to extend the slump life of the concrete.

**503.07 Reinforcing Steel.** Reinforcing steel used in the construction of drilled shafts shall conform to Section 602. When necessary, vertical bars shall be bundled in order to maximize clear space between vertical reinforcement bars. Rolled hoops or bundled spirals shall be used in order to maximize the clear space between horizontal reinforcement. Reinforcing steel cages for drilled shafts with varying shaft and socket diameters shall be designed with a single, uniform diameter. At all times, the reinforcing bars and fabricated steel reinforcing cage shall be supported off the ground surface and shall be protected from contamination with mud, oils and solvents, and other deleterious materials. The steel should be free of excessive rust (flaking, peeling, thick coating) at the time of cage placement into the hole. Any contamination or excessive rust shall be cleaned and removed by the Contractor to the Engineer's acceptance prior to placement.

**503.08 Casings.** All permanent structural casing shall be of steel conforming to ASTM A36/A36M or ASTM 252 Gr 2 unless specified otherwise in the Plans. All splicing of permanent structural casing shall be in accordance with Section 6.13.3, "Welded Connections," of the AASHTO LRFD Bridge Design Specifications. All casing shall be watertight and clean prior to placement in the excavation. Where the minimum thickness of the casing is specified in the Plans, it is specified to satisfy structural design requirements only. The Contractor shall increase the casing thickness from the minimum specified thickness, as necessary and accepted by the Engineer, to satisfy the construction installation requirements.

All permanent casing shall be of ample strength to resist damage and deformation from transportation and handling, installation stresses, and all pressures and forces acting on the casing. For permanent nonstructural casing, corrugated casing may be used. The diameter of permanent casing shall be as shown on the Plans unless a larger diameter casing is approved by the Engineer. When a larger size permanent casing is approved by the Engineer, no additional payment will be made for the increased weight of casing steel or the increased quantity of drilled shaft excavation and concrete.

All temporary casing shall be a smooth wall structure steel except where corrugated metal pipe is shown in the Plans as an acceptable alternative material. All temporary casing shall be of ample strength to resist damage and deformation from transportation and handling, installation and extraction stresses, and all pressures and forces acting on the casing. The casing shall be capable of being installed and removed without deforming and causing damage to the completed shaft and without disturbing the surrounding soil. Temporary casing shall be completely removed, unless otherwise shown on the Plans or approved by the Engineer. The outside diameter of temporary casing shall not be less than the specified diameter of the shaft.

**503.09 Mineral Slurry.** Mineral Slurry shall be used in conformance with the quality control plan specified in Subsection 503.02.(b).(5)

Mineral slurry shall conform to the following requirements:

Property	Test	Requirement
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Density (pcf)	Mud Weight (Density) API 13B-1, Section 1	64.3 to 72
Viscosity (seconds/quart)	Marsh Funnel and Cup API 13b-1, Section 2.2	28 to 50
pH	Glass Electrode, pH Meter, or pH Paper	8 to 11
Sand Content (percent)	API 13B-1, Section 5	4.0 max immediately prior to placing concrete

**503.10 Polymer Slurry.** Polymer slurries, either natural or synthetic, shall be used in conformance with the manufacturer's recommendations, and shall conform to the quality control plan specified in Subsection 503.02.(b).(5) of this Specification. The polymer slurry shall conform to the following requirements:

Property	Test	Requirement
Density (pcf)	Mud Weight (Density) API 13B-1, Section 1	64.3 max.
Viscosity (seconds/quart)	Marsh Funnel and Cup API 13b-1, Section 2.2	32 to 135
pH	Glass Electrode, pH Meter, or pH Paper	8 to 1.5
Sand Content (percent)	API 13B-1, Section 5	1.0 max immediately prior to placing concrete

The sand content of polymer slurry prior to final cleaning and immediately prior to placing concrete shall be less than or equal to 1.0 percent, in accordance with American Petroleum Institute API 13B-1, Section 5. Slurry temperature shall be at least 40°F when tested.

**503.11 Water Slurry.** Water may be used as slurry when casing is used for the entire length of the drilled hole, or to stabilize the bedrock below the temporary casing provided that the method of drilled shaft installation maintains stability at the bottom of the shaft excavation. Water slurry shall conform to the following requirements:

Property	Test	Requirement
Density (pcf)	Mud Weight (Density) API 13B-1, Section 1	64 max.
Sand Content (percent)	API 13B-1, Section 5	1.0 max

**503.12 Access Tubes for CSL Testing.** Access tubes for CSL testing shall be steel pipe of 0.145 inches minimum wall thickness and at least 1-1/2 inch inside diameter. The access tubes shall have a round, regular inside diameter free of defects and obstructions, including all pipe joints, in order to permit the free, unobstructed passage of 1.3 inch maximum diameter source and receiver probes used for the CSL tests. The access tubes shall be non-galvanized, watertight, free from corrosion, and with clean internal and external faces to ensure good bond between the concrete and the access tubes. The access tubes shall be fitted with watertight threaded caps on the bottom and the top. Grout for filling the access tubes at the completion of the CSL tests shall be a neat cement grout with a minimum water/cement ratio of 0.45.

## CONSTRUCTION REQUIREMENTS

**503.13 Drilled Shaft Excavation.** Drilled shafts shall be excavated to the required depth as shown in the Plans or as directed by the Engineer. The excavation and drilling equipment shall have adequate capacity, including power, torque and down pressure to excavate a hole of both the maximum diameter and to a depth of 20 feet or 20 percent beyond the maximum shaft length shown on the Plans, whichever is greater. Blasting will only be permitted if specifically stated on the Plans or authorized in writing by the Engineer. Once the excavation operation has been started, the excavation shall be conducted in a continuous operation until the excavation of the shaft is completed except for pauses and stops as noted using approved equipment capable of excavating through the type of material expected. Pauses or interruptions during this excavation operation will not be allowed except for casing installation, casing splicing and removal of materials or obstructions. Drilled shaft excavation operation interruptions not conforming to this definition shall be considered stops. The Contractor shall provide temporary casing at the site in sufficient quantities to meet the needs of the anticipated construction method.

If the drilled shaft excavation is not complete at the end of the shift or series of continuous shifts, the drilled shaft excavation operation may be stopped provided the Contractor protects the shaft as indicated in Subsection 503.13.(b) of this Specification before the end of the work day.

If slurry is present in the shaft excavation, the Contractor shall conform to the requirements of Subsection 503.13 (b).5.(2) of this Specification regarding the maintenance of the minimum level of drilling slurry throughout the stoppage of the shaft excavation operation, and shall recondition the slurry to the required slurry properties in accordance with Sections 503.09, 503.10 and 503.11 of this Specification prior to recommencing shaft excavation operations.

Sidewall over reaming shall be performed when the time for shaft excavation exceeds 24 hours (measured from the beginning of excavation below the casing when casing is used) before the start of concrete placement. Sidewall over reaming shall also be performed when the sidewall of the hole is determined by the Engineer to have softened due to the excavation methods, swelled due to delays in the start of concrete placement, or degraded because of slurry cake buildup. Over reaming thickness shall be a minimum of 1/2-inch or as directed by the Engineer. Over reaming may be accomplished with a grooving tool, over reaming bucket, or other equipment approved by the Engineer. If over reaming is required as a result of the excavation time exceeding the time limit specified herein, or as a result of excavation methods not in compliance with the approved Drilled Shaft Installation Plan, the Contractor shall bear the costs associated with both sidewall over reaming and additional drilled shaft concrete related to over reaming.

Excavation to the foundation cap elevation shall be completed before drilled shaft construction begins unless otherwise noted in the Contract Documents or approved by the Engineer. Any disturbance to the foundation cap area caused by shaft installation shall be repaired by the Contractor prior to placing the cap concrete. When drilled shafts are to be installed in conjunction with embankment construction, the Contractor shall construct drilled shafts after placement of the embankment fill unless otherwise shown on the Contract Documents or approved by the Engineer. Drilled shafts installed prior to the completion of the embankment fill shall not be capped until the fill has been placed to the bottom of cap level.

- (a) *Drilled Shaft Excavation.* The contractor may excavate the drilled shaft without excavation protection provided the Contractor can demonstrate that the ground water level and soil and rock conditions are suitable for the dry construction method. The dry construction method consists of drilling the shaft excavation, removing accumulated water and loose material from the excavation, placing the reinforcing cage, and concreting the shaft in relatively dry excavation. The Engineer will approve the dry construction method only if the shaft excavation demonstrates that the following conditions are met: less than 12 inches of water accumulates above the base over a period of one hour when no pumping is permitted, the sides and bottom of the hole remain stable without detrimental caving, sloughing or swelling between the completion of excavation and concrete placement, all loose material and water can be satisfactorily removed prior to inspection and concrete placement ( less than 2 inches of water will be permitted in the bottom of the shaft excavation at the time of concrete placement), and the Engineer can visually inspect the sides and bottom of the shaft prior to placing the concrete. The drilled shaft excavations shall not be left open overnight unless cased full depth or otherwise protected against sidewall instability. An open excavation is defined as a drilled shaft that has not been filled with concrete, or temporarily backfilled with a material approved by the Engineer in accordance with Subsection 503.02 (b) of this Specification or protected in accordance with Subsection 503.13 (b). The use of slurry to protect a drilled shaft during a drilling stoppage or overnight shutdown may be approved by the Engineer. The excavation shall be protected with a suitable cover which will prevent persons or materials from falling into the hole. Casing of drilled shafts in stable rock formations during stoppages is not required if accepted by the Engineer unless shown on the Plans or specified herein. All OSHA safety requirements near the drilled shaft shall be followed.
- (b) *Drilled Shaft Excavation Protection Methods.* The Contractor bears full responsibility for selection and execution of the methods of stabilizing and maintaining the drilled shaft excavation. The walls and bottom of the drilled shaft excavation shall be protected so that sidewall caving and bottom heaves are prevented from occurring, and so that the soil adjacent to the drilled shaft is not disturbed. For shafts where the soils above the bedrock do not contribute to the bearing calculations, the soils surrounding the temporary casing may be disturbed during the installation of temporary casing using uncontrolled in-situ slurries.

Acceptable protection methods include the use of casing, drilling slurry, or both.

### **1. Temporary Casing Construction Method**

In stable soils, the Contractor shall conduct casing installation and removal operations and drilled shaft excavation operations such that the adjacent soil outside the casing and drilled shaft excavation for the full height of the drilled shaft is not disturbed. Disturbed soil is defined as soil whose geotechnical properties have been changed from those of the original in-situ soil, and whose altered condition adversely affects the performance of the drilled shaft foundation. For shafts where the soils above the bedrock do not contribute to the bearing calculations, the soils surrounding the temporary casing may be disturbed during the installation of temporary casing using uncontrolled in-situ slurries.

If the Contractor is utilizing casing that is adequately sealed into competent soils such that water cannot enter the excavation, the Contractor may, with the Engineer's approval, continue excavation without protection in soils below the water table provided the water level within the casing does not rise or exhibit flow. If casing is sealed into the underlying bedrock, water may infiltrate the shaft below the casing. Excavation of the bedrock may continue without the use of casing or slurry if the shaft remains stable.

As the temporary casing is withdrawn, sufficient head of fluid concrete must be maintained to ensure that water or slurry outside the temporary casing will not breach the column of freshly placed concrete. Casing extraction shall be at a slow, uniform rate with the pull in line with the shaft axis. Excessive rotation of the casing shall be avoided to limit deformation of the reinforcing steel cage.

The Contractor shall remove all temporary casings from the excavation as concrete placement is completed, unless permission has been received from the Engineer to leave specified temporary casings in place.

### **2. Permanent Casing Construction Method**

When permanent casing is specified, excavation shall conform to the specified outside diameter of the drilled shaft. After the casing has been filled with concrete, all void space occurring between the casing and drilled shaft excavation shall be filled with a material which approximates the geotechnical properties of the in-situ soils, in accordance with the Drilled Shaft Installation Plan specified in subsection 503.02.(b) of this Specification and as approved by the Engineer.

Tops of permanent casings for the drilled shafts shall be removed to the top of the drilled shaft or finished ground line, whichever is lower, unless the top of permanent casing is shown in the Plans at a different elevation. For those drilled shafts constructed within a permanent body of water, tops of permanent casings for drilled shafts shall be removed to the low water elevation unless otherwise shown on the Plans or directed otherwise by the Engineer. Casing used for forming shafts installed through a body of water shall not be removed.

### **3. Alternative Casing Methods**

When approved by the Engineer, installation of casing using rotating or oscillating methods will be permitted. Use of this alternative casing method shall be in accordance with the equipment and procedures shown in the approved Drilled Shaft Installation Plan, and shall comply with all other requirements specified herein. Drilled shaft casing shall be equipped with cutting teeth or a cutting shoe and installed by either rotating or oscillating the casing.

### **4. Uncontrolled In-Situ Slurry**

The uncontrolled in-situ slurry consists of in-situ soils from the drilled shaft mixed with water. For shafts where the soils above the bedrock do not contribute to the bearing calculations, the contractor can use uncontrolled in-situ slurry to install temporary casing. For shafts where the soils above the bedrock do contribute to the bearing calculations, the use of uncontrolled in-situ slurry to install temporary casing shall not be allowed. Slurry in accordance with Subsection 503.09, 503.10 and 503.11 of this specification may be required at the engineer's request if the drilled shaft does not remain stable using uncontrolled in-situ slurry.

## **5. Slurry**

The Contractor shall use slurry in accordance with Subsections 503.09, 503.10 and 503.11 of this Specification to maintain a stable excavation during drilled shaft excavation and concrete placement operations once water begins to enter the drilled shaft excavation and remain present.

The Contractor shall use slurry to maintain stability during drilled shaft excavation and concrete placement operations in the event that water begins to enter the drilled shaft excavation at a rate of greater than twelve inches per hour, or if the Contractor is not able to restrict the amount of water in the drilled shaft to less than three inches prior to concrete placement, or to equilibrate water pressure on the sides and base of the drilled shaft excavation when groundwater is encountered or anticipated based on the available subsurface data.

### **(1) Slurry Technical Assistance**

If slurry is used, the manufacturer's representative, as identified to the Engineer in accordance with Subsection 503.02. (c) of this Specification, shall provide technical assistance for the use of the slurry.

The manufacturer's representative or the Contractor's employee trained in the use of the slurry, as identified to the Engineer in accordance with Subsection 503.02.(c) of this Specification, shall be present at the site throughout the shaft slurry operations for this project to perform the duties specified above.

### **(2) Minimum Level of Slurry in the Excavation**

When slurry is used to maintain a stable excavation, the slurry level in the excavation shall be maintained to obtain hydrostatic equilibrium throughout the construction operation at a height required to provide and maintain a stable hole, but not less than 5 feet above the water table.

Recommended slurry levels are as follows:

- (1) not less than five feet above the water table for mineral slurries,
- (2) not less than ten feet above the water table for water and uncontrolled in-situ slurries,
- (3) not less than ten feet above the water table for polymer slurries, except when a lesser dimension is specifically recommended by the slurry manufacturer for the site conditions and construction methods.

The Contractor shall provide casing, or other means, as necessary to meet these requirements.

The slurry level shall be maintained above all unstable zones a sufficient distance to prevent bottom heave, caving or sloughing of those zones.

Throughout all stops in drilled shaft excavation operations, the Contractor shall monitor and maintain the slurry level in the excavation the greater of the following elevations:

- (1) no lower than the water level elevation outside the drilled shaft,
- (2) elevation as required to provide and maintain a stable hole.

### **(3) Cleaning Slurry**

The Contractor shall clean, re-circulate, de-sand, or replace the slurry, as needed, in order to maintain the required slurry properties. Sand content will only be required to be within specified limits immediately prior to concrete placement.

**503.14 Obstructions.** When obstructions are encountered, the Contractor shall notify the Engineer promptly. An obstruction is defined as a specific object (including, but not limited to, boulders, logs, and manmade objects) encountered during the drilled shaft excavation operation which prevents or hinders the advance of the drilled shaft excavation. When efforts to advance past the obstruction to the design drilled shaft tip elevation result in the rate of advance of the drilled shaft drilling equipment being significantly reduced relative to the rate of advance for the portion of the drilled shaft excavation in the geological unit that contains the obstruction, then the Contractor shall remove, bypass or break up the obstruction under the provisions of Subsection 503.24 of this Specification. Blasting will not be permitted unless approved in writing by the Engineer.

Drilling tools that are lost in the excavation will not be considered obstructions, and shall be promptly removed by the Contractor. All costs due to lost tool removal will be borne by the Contractor including, but not limited to, costs associated with the repair of hole degradation due to removal operations or an excessive time that the hole remains open.

**503.15 Protection of Existing Structures and Drilled Holes.** The Contractor shall control operations to prevent damage to existing structures and recently drilled holes, utilities, roadways and other facilities. Preventative measures shall include, but are not limited to, selecting construction methods and procedures that will prevent excessive caving of the drilled shaft excavation and monitoring and controlling the vibrations from the driving of casing or sheeting, drilling of the shaft, or from blasting, if permitted.

**503.16 Slurry Sampling and Testing.** Mineral slurry and polymer slurry shall be mixed and thoroughly hydrated in slurry tanks, lined ponds, or storage areas. The Contractor shall draw sample sets from the slurry storage facility and test the samples for conformance with the appropriate specified material properties before beginning slurry placement in the drilled hole. Slurry shall conform to the quality control plan included in the Drilled Shaft Installation Plan in accordance with Subsection 503.02.(b).(5) of this Specification and approved by the Engineer. A sample set shall be composed of samples taken at mid-height and within two feet of the bottom of the storage area.

The Contractor shall sample and test all slurry in the presence of the Engineer, unless otherwise approved by the Engineer. The date, time, names of the persons sampling and testing the slurry, and the results of the tests shall be recorded. A copy of the recorded slurry test results shall be submitted to the Engineer at the completion of each drilled shaft, and during construction of each drilled shaft when requested by the Engineer.

Sample sets of all slurry, composed of samples taken at mid-height and within two feet of the bottom of the drilled shaft, shall be taken and tested during drilling as necessary to verify the control of the properties of the slurry. As a minimum, sample sets of polymer slurry shall be taken and tested at least once every four hours after beginning its use during each shift. Sample sets of all slurry, as specified, shall be taken and tested immediately prior to placing concrete.

The Contractor shall demonstrate to the satisfaction of the Engineer that stable conditions are being maintained. If the Engineer determines that stable conditions are not being maintained, the Contractor shall immediately take action to stabilize the shaft. The Contractor shall submit a revised Drilled Shaft Installation Plan which addresses the problem and prevents future instability. The Contractor shall not continue with drilled shaft construction until the damage which has already occurred is repaired in accordance with the Specifications, and until receiving the Engineer's approval of the revised Drilled Shaft Installation Plan. The Engineer will evaluate the revised Drilled Shaft Installation Plan for conformance with the Contract Plans and Specifications within five working days after receipt of the submission.

**503.17 Drilled Shaft Excavation Inspection.** The Contractor shall use appropriate means such as a cleanout bucket, air lift, or hydraulic pump to clean the bottom of the excavation of all drilled shafts. For wet drilled shaft excavation in soils, the base of the excavation shall be covered with not more than 3 inches of sediment or loose or disturbed material just prior to placing concrete. For dry drilled shaft excavations in soils, the base of excavation shall be covered with not more than 1.5 inches sediment or loose or disturbed material just prior to placing concrete. For wet and dry drilled shaft excavations in rock, the base of the excavation shall be covered with not more than 0.5 inch for 50 percent of the base area of sediment or loose or disturbed material just prior to placing concrete.

The excavated drilled shaft will be inspected and approved by the Engineer prior to proceeding with construction. The bottom of the excavated drilled shaft shall be sounded with an airlift pipe, a tape with a heavy weight attached to the end of the tape, a borehole camera with visual sediment depth measurement gauge, or other means

acceptable to the Engineer to determine that the drilled shaft bottom meets the requirements in the Contract. The contractor shall supply all needed equipment required to inspect the drilled shaft excavation.

**503.18 Assembly and Placement of Reinforcing Steel.** The contractor shall show bracing and any extra reinforcing steel required for fabrication of the cage on the shop drawings. The contractor will be responsible for engineering the temporary support and bracing of the reinforcing cages to ensure that they maintain their planned configuration during assembly, transportation and installation.

The reinforcing cage shall be rigidly braced to retain its configuration during handling and construction. Individual or loose bars will not be permitted. All (100%) intersections of vertical and horizontal bars must be tied. At least 4 vertical bars of each cage, equally spaced around the circumference, shall be tied at all reinforcement intersections with double wire ties. The remaining reinforcement intersections in each cage shall be tied with single wire ties.

The reinforcement shall be carefully positioned and securely fastened to provide the minimum clearances specified or shown on the Plans, and to ensure that no displacement of the reinforcing steel cage occurs during placement of the concrete. Splicing of the reinforcement cage during placement of the cage in the shaft excavation will not be permitted unless otherwise shown on the Plans or approved by the Engineer. If the reinforcing cage is spliced during placement of the cage into the drilled shaft excavation, the splice details and location of the splices shall be in accordance with the Plans and the approved Drilled Shaft Installation Plan. In addition, the work shall be performed within the time limits specified in Subsection 503.13

The steel reinforcing cage shall be securely held in position throughout the concrete placement operation. The reinforcing steel cage shall be supported from the top during the placement of the concrete to achieve the clearances shown on the plans. Setting the cage on the bottom of the hole will not be permitted. The support system shall be concentric to prevent racking and displacement of the cage. The reinforcing steel in the drilled shaft shall be tied and supported so that the location of the reinforcing steel will remain within allowable tolerance. Concrete spacers or other approved non-corrosive spacing devices shall be used at sufficient intervals (near the bottom, the top and at intervals not exceeding 10 feet vertically) to ensure concentric spacing for the entire cage length. The number of spacers required at each level will be one spacer for each foot of excavation diameter, with a minimum of four spacers at each level. The spacers shall be of adequate dimension to ensure an annular space between the outside of the reinforcing cage and the side of the excavation along the entire length of the drilled shaft as shown in the Plans. Acceptable feet made of plastic, or concrete (bottom supports) shall be provided to ensure that the bottom of the cage is maintained at the proper distance above the base of the excavation unless the cage is suspended from a fixed base during the concrete pour.

Minimum concrete cover to reinforcing steel shall be as follows:

<b>Drilled Shaft Diameter</b>	<b>Minimum Concrete Cover</b>
Less than or equal to 3'-0"	3"
Greater than 3'-0" and less than 5'-0"	4"
5'-0" or larger	6"

If concrete placement does not immediately follow the cage placement, the Engineer may order the steel to be removed from the excavation so that the integrity of the excavation, including the presence of loose material in the bottom of the hole, and the surface condition of the reinforcing steel may be determined by inspection.

Bracing steel which constricts the interior of the reinforcing cage must be removed after lifting the cage if freefall concrete or wet tremie methods of concrete placement are to be used.

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

**503.19 Concrete Placement, Curing and Protection.** Concrete placement shall commence as soon as possible after completion of drilled shaft excavation by the Contractor and inspection by the Engineer. Immediately prior to commencing concrete placement, the drilled shaft excavation and the properties of the slurry (if used) shall conform to Subsections 503.09, 503.10 and 503.11 of this Specification. The CSL access tubes shall be filled with potable water before concrete placement and the top watertight threaded caps shall be reinstalled. Concrete placement shall continue in one operation to the top of the drilled shaft, or as shown in the Plans.

If water is not present (a dry shaft), the concrete shall be deposited through the center of the reinforcement cage by tremie or free-fall preventing segregation of aggregates. The concrete shall be placed such that the free-fall is vertical down the center of the drilled shaft without hitting the sides, the steel reinforcing bars, or the steel reinforcing bar cage bracing.

If water exists in amounts greater than two inches in depth or enters at a rate of more than twelve inches per hour then the drilled shaft excavation must be filled with slurry to at least the level specified in Subsection 503.13 (b).5.(2) and concrete placed by tremie methods outlined in this section.

The elapsed time for concrete placement shall not exceed the time limit defined in the approved Drilled Shaft Installation Plan and demonstrated by a successful technique shaft or test shaft. The concrete placement time shall commence at the mixing of the concrete and extend through to the completion of placement of the concrete in the drilled shaft excavation, including removal of any temporary casing. For wet placement methods, the placement time shall start at the batching of the initial load of concrete to be placed in the shaft. Prior to concrete placement, the Contractor shall provide test results of both a trial mix and a slump loss test conducted by an approved testing laboratory using approved methods to demonstrate that the concrete meets this defined placement time limit. The concrete mix shall maintain a slump of 4 inches or greater over the defined placement time limit as demonstrated by trial mix and slump loss tests. The trial mix and slump loss tests shall be conducted at ambient temperatures appropriate for site conditions. Ambient air temperature at the time of concrete placement shall not be greater than the ambient temperature at the time of the concrete trial tests and slump loss tests.

All admixtures, when approved for use, shall be adjusted for the conditions encountered on the job so the concrete remains in a workable plastic state throughout the defined placement time limit.

Before placing any fresh concrete against concrete deposited in water or slurry (construction joint), the Contractor shall remove all scum, laitance, loose gravel and sediment on the surface of the concrete deposited in water or slurry, and chip off any high spots on the surface of the existing concrete that would prevent any steel reinforcing bar cage from being placed in the position required by the Plans.

The Contractor shall not perform foundation piling driving or casing installation using oscillation method within a radius of 20 feet, nor drilled shaft excavation operations within a clear distance of three diameters of a newly poured drilled shaft 24 hours of the placement of concrete and only when the concrete has reached a minimum compressive strength of 1800 psi.

For any portion of the caisson socketed in fine grained bedrock susceptible to slaking and degradation such as, but not limited to, claystone, siltstone, or shale and provided the proper slurry properties have been achieved. If the concrete is not placed within four hours of drilling, the Contractor shall drill into the bedrock an additional 1/3 of the plan specified rock socket prior to placing the concrete. The reinforcing cage shall extend to the new tip elevation.

Throughout the underwater concrete placement operation, the discharge end of the tube shall remain submerged in the concrete at least five feet and the tube shall always contain enough concrete to prevent water from entering. The concrete placement shall be continuous until the work is completed, resulting in a seamless, uniform shaft. If the concrete placement operation is interrupted, the Engineer may require the contractor to prove by core drilling or other tests that the drilled shaft contains no voids or horizontal joints. If testing reveals voids or joints, the Contractor shall repair them or replace the drilled shaft at no expense to the Owner. Responsibility for coring and testing costs, and calculation of time extension, shall be in accordance with Section 503.21 of this Specification. The Contractor shall use a concrete pump or gravity tremie. A tremie shall have a hopper at the top that empties into a watertight tube at least eight inches in diameter. If a pump is used, a watertight tube shall be used with a minimum diameter of four inches. The discharge end of the tube on the tremie or concrete pump line shall include a device to seal out water or slurry while the tube is first filled with concrete. In lieu of a seal at the discharge end of the pipe, the Contractor may opt to place a "Pig" or "Rabbit" in the hopper prior to concrete placement which moves through the tremie when pushed by the concrete, forcing water or slurry from the tremie pipe. The Contractor shall complete a concrete yield plot for each wet shaft poured by tremie methods. This yield plot will be submitted to the Engineer within 24 hours of completion of the concrete pour.

The hopper and tubes shall not contain aluminum parts that will have contact with the concrete. The inside and outside surfaces of the tubes shall be clean and smooth to allow both flow of concrete and the unimpeded withdrawal of the tube during concrete placement.

**503.20 Drilled Shaft Construction Tolerances.** Drilled shafts shall be constructed so that the center of the poured shaft at the top of the drilled shaft or mudline, whichever is lower, is within the following horizontal tolerances:

<b>Drilled Shaft Diameter</b>	<b>Tolerance</b>
Less than or equal to 2'-0"	3"
Greater than 2'-0" and less than 5'-0"	4"
5'-0" or larger	6"

Drilled shafts in soil and rock shall be within 1.5 percent of plumb. Plumbness shall be measured from the top of poured drilled shaft elevation or mudline, whichever is lower. During drilling or excavation of the drilled shaft, the Contractor shall make frequent checks on the plumbness, alignment, and dimensions of the drilled shaft. Any deviation exceeding the allowable tolerances shall be corrected with a procedure approved by the Engineer.

Drilled shaft steel reinforcing bars shall be no higher than six inches above or three inches below the plan elevation.

The reinforcing cage shall be concentric with the drilled shaft excavation within a horizontal tolerance of 1-1/2 inches.

The top elevation of the completed drilled shaft shall have a tolerance of plus one inch or minus three inches.

The diameter of the drilled shaft shall not be less than the diameter on the Plans.

Tolerances for casings shall be in accordance with American Pipe Institute tolerances applicable to regular steel pipe.

Drilled shaft excavations and completed drilled shafts not constructed within the required tolerances will be considered defective. The Contractor shall be responsible for correcting all defective drilled shafts to the satisfaction of the Engineer. Materials and work necessary, including engineering analysis and redesign, to complete corrections for out-of-tolerance drilled shafts shall be furnished without either cost to the Owner or an extension of the completion date of the project. Redesign drawings and computations submitted by the Contractor shall be signed by a registered Professional Engineer licensed in the State of Colorado.

## **TESTING AND VERIFICATION**

**503.21 Integrity Testing.** CSL testing shall be performed in accordance with ASTM D6760 on all drilled shafts in bridge bents or piers considered nonredundant in the plans. For all other drilled shafts, perform CSL testing for wet placement shafts using slurry and tremie concrete methods and drilled shafts selected by the Engineer. The minimum number of shafts tested is the number of shafts indicated in the plans. The Engineer may increase the number of shafts tested as deemed necessary. The Contractor shall accommodate the CSL testing by furnishing and installing access tubes in accordance with Subsection 503.12 of this Specification.

The Contractor shall install access tubes for CSL testing in all drilled shafts, except as otherwise noted, to permit access for the CSL test probes. If, in the opinion of the Engineer, the condition of the drilled shaft excavation permits drilled shaft construction in the dry, the Engineer may specify that the testing be omitted.

The Contractor shall securely attach the access tubes to the interior of the reinforcement cage of the drilled shaft. One access tube shall be furnished and installed for each foot of drilled shaft diameter, rounded up to the nearest whole number, unless otherwise shown in the Plans. A minimum of three tubes will be required. The access tubes shall be placed around the drilled shaft, inside the spiral or hoop reinforcement and three inches clear of the vertical reinforcement, at a uniform spacing measured along the circle passing through the centers of the access tubes. If these minimums cannot be met due to close spacing of the vertical reinforcement, then the access tubes shall be bundled with the vertical reinforcement.

If trimming the cage is required and access tubes for CSL testing are attached to the cage, the Contractor shall either shift the access tubes up the cage, or cut the access tubes provided that the cut tube ends are adapted to receive the watertight cap as specified.

The access tubes shall be installed in straight alignment and as near to parallel to the vertical axis of the reinforcement cage as possible. The access tubes shall extend from the bottom of the drilled shaft to at least two feet above the top of the drilled shaft. Couple tubes as required with threaded couplers, such that inside of tube remains flush. The Contractor shall clear the access tubes of all debris and extraneous materials before installing the access tubes. Care shall be taken to prevent damaging the access tubes during reinforcement cage installation and concrete placement operations in the drilled shaft excavation.

The access tubes shall be filled with potable water before concrete placement, and the top watertight threaded caps shall be reinstalled.

Prior to performing any crosshole sonic log testing operations specified in this subsection, the Contractor shall remove the concrete at the top of the drilled shaft down to sound concrete.

The Contractor shall engage a qualified Specialty Engineer to perform the CSL testing. The qualified CSL Specialty Engineer must have a minimum three years of experience of CSL testing and have a Colorado Licensed Professional Engineer supervising the collection and interpretation of data. The contractor shall provide all necessary assistance to the CSL Specialty Engineer to satisfactorily perform the testing.

The testing shall be performed after the drilled shaft concrete has cured at least 96 hours. Additional curing time prior to testing may be required if the drilled shaft concrete contains admixtures, such as set retarding admixture or water reducing admixture. The additional curing time prior to testing required under these circumstances shall not be grounds for additional compensation or extension of time to the Contractor. No subsequent construction shall be performed on the completed drilled shaft until the CSL tests are approved and the drilled shaft accepted by the Engineer.

After placing the drilled shaft concrete and before beginning the CSL testing of a drilled shaft, the Contractor shall inspect the access tubes. Each access tube that the test probe cannot pass through shall be replaced, at the Contractor's expense, with a two inch diameter hole cored through the concrete for the entire length of the drilled shaft. Unless directed otherwise by the Engineer, cored holes shall be located approximately six inches inside the reinforcement and shall not damage the drilled shaft reinforcement. Descriptions of inclusions and voids in cored holes shall be logged and a copy of the log shall be submitted to the Engineer. Findings from cored holes shall be preserved, identified as to location, and made available for inspection by the Engineer.

The Engineer may approve the continuation of drilled shaft construction prior to approval and acceptance of the first shaft if the Engineer's observations of the construction of the first shaft are satisfactory, including, but not limited to, conformance to the Drilled Shaft Installation Plan as approved by the Engineer, and the Engineer's review of Contractor's daily reports and inspector's daily logs concerning excavation, steel reinforcing bar placement, and concrete placement.

Drilled shafts with velocity reduction exceeding 30% are not acceptable without additional offset CSL testing and Three Dimensional (3-D) Tomography analysis

If subsequent testing at a drilled shaft indicates the presence of a defect(s) in the drilled shaft, the testing costs and the delay costs resulting from the additional testing shall be borne by the Contractor. If this additional testing indicates that the drilled shaft has no defect, the testing costs and the delay costs resulting from the additional testing will be paid by the Owner, and, if the drilled shaft construction is on the critical path of the Contractor's schedule, a time extension equal to the delay created by the additional testing will be granted.

If the Engineer determines a drilled shaft is unacceptable based on the CSL tests and tomographic analyses, or observes problems during drilled shaft construction, coring of the shaft to allow further evaluation and repair is required, or the shaft has to be replaced. If coring to allow further evaluation of the shaft and repair is chosen, one or more core samples shall be taken from each unacceptable shaft for full depth of the shaft or to the depth directed by the Engineer. The Engineer will determine the number, location, and diameter of the cores based on the results of 3-D tomographic analysis of offset and horizontal CSL data. An accurate log of cores has to be kept. Properly mark and place the cores in a crate showing the shaft depth at each interval of core recovery. Transport the cores, along with five copies of the coring log to the Engineer. Perform strength testing by an AASHTO certified lab on portions of the cores that exhibit questionable concrete as determined by the Engineer. If the drilled shaft offset CSL testing, 3-D tomographic analyses and coring indicate the shaft is defective, propose

remedial measures for approval by the Engineer. Such improvement may consist of, but is not limited to correcting defective portions of the shaft, providing straddle shafts to compensate for capacity loss, or providing a replacement shaft. Repair all detected defects and conduct post repair integrity testing using horizontal and offset CSL testing and 3-D tomographic imaging as described in this Section. Perform all work described in this Section at no additional cost to the Department, and with no increase in Contract Time.

All access tubes and cored holes shall be dewatered and filled with a 4000 psi grout after tests are completed and the drilled shaft is accepted. The access tubes and cored holes shall be filled using grout tubes that extend to the bottom of the tube or hole or into the grout already placed.

**503.22 Drilled Shafts Load Tests.** Test shafts shall be installed at the locations shown on the Plans unless otherwise directed or approved by the Engineer.

Test shafts shall be installed to the same dimensions, details and elevations shown on the Plans, and shall be installed using the same equipment and installation procedures proposed for installation of the foundation drilled shafts.

If the equipment or procedures are changed following the completion of load testing, the Contractor shall install additional load test shafts, and conduct additional load tests as directed by the Engineer at no additional cost to the Owner.

A stamped report of load test results within five business days of the testing completion is required. Load testing results will be evaluated by the Engineer before installing any production drilled shafts, unless otherwise authorized by the Engineer, to allow for design modifications based on the load test results. Load test data as reported shall conform to the Drilled Shaft Foundation Testing (DSHAFT) and be available in electronic form at the project website (<http://srg.cce.iastate.edu/shaft>).

- (a) *Static Load Tests.* Static load tests shall be performed in accordance with the procedures specified in ASTM D 1143.
- (b) *Force Pulse (Rapid) Load Tests.* Force pulse (rapid) load tests shall be performed in accordance with the procedures specified in ASTM D 7383.

## METHOD OF MEASUREMENT

**503.23** Drilled caisson will be measured by the linear foot from the elevation shown on the plans to the bottom of the hole as drilled.

Each approved splice of the reinforcing cage for additional length of caisson will be measured as ½ linear foot of additional length of drilled caisson.

## BASIS OF PAYMENT

**503.24** The unit price of drilled shafts shall be full compensation for making all excavations; hauling and disposal of excavated material; provision and disposal of slurry, performing all necessary pumping; furnishing and placing required concrete and reinforcement steel, including the reinforcement projecting above the tops of the drilled shafts necessary for splicing and any intermediate reinforcement splices; furnishing and placing of CSL tubes; all backfilling; furnishing, placing, and removing temporary casings; furnishing permanent casing if required to complete the work; and for furnishing all tools, labor, equipment, and incidentals necessary to complete the work. Costs associated with repairing defects found in the drilled shaft shall be included in the cost of the drilled shaft.

- (a) *Payment.* The accepted quantities for drilled caissons will be paid for at the Contract unit price per linear foot except for price adjustments allowed in (b) below.

Payment will be made under:

<b>Pay Item</b>	<b>Pay Unit</b>
Drilled Caisson (XX Inch dia.)	Linear Foot
Load Tests	Each
CSL Testing	Each

Obstruction Encounter and Removal will not be measured but will be paid for under Force Account Item, F/A Obstruction Encounter and Removal.

(b) *Price Adjustments.* When the Engineer orders holes to be drilled to a lower elevation than shown on the plans, compensation for additional depth will be as follows:

<b>Additional Length</b>	<b>Compensation</b>
0 to 5 feet	Contract Unit Price
Over 5 feet to 15 feet	Contract Unit Price plus 15%
Over 15 feet	As provided in subsection 109.04

Additional compensation will not be paid for the portions of a caisson that are extended due to the Contractor's method of operation, as determined by the Engineer.