



## SECTION 701

### DRILLED SHAFTS

**701.1 Description.** This work shall consist of constructing cast-in-place reinforced concrete drilled shafts and rock sockets, as required, to serve as a structural foundation. This work shall provide reinforced concrete shafts cast in cylindrically excavated holes extending sufficiently into soil or sound rock to adequately support the structure and all externally applied loads for which the shaft was designed. The drilled shaft foundation, including the rock socket, where required, shall be constructed in accordance with these specifications, as shown on the plans and in accordance with other specifications included in the contract documents. When directed by the engineer, corrections made by the contractor will be noncompensable and any effect on time of performance nonexcusable.

**701.2 Preconstruction Submittals.** At least 30 days prior to drilled shaft construction, the contractor shall submit to the engineer for review an installation plan for the construction of drilled shafts. The installation plan shall be of sufficient detail to outline the contractor's intended overall construction sequence and methods of excavation for the drilled shafts, including use of slurry, placement of reinforcing steel, details of concrete delivery to the site, an emergency construction joint method, placement of concrete in a continuous pour, including operational procedures for tremie or pump, and methods to prevent and handle delays in concrete batching and delivery to the site. The installation plan shall include details of casings to be used, if applicable, including calculations showing the ability of the casing to withstand anticipated hydraulic and earth pressures, and to withstand stresses due to installation without undue deformation. These details shall include methods for casing handling, splicing, straightening and out-of-round correction. Calculations included in the installation plan shall be signed and sealed by a registered professional engineer licensed to practice in the State of Missouri.

**701.3 Material.** All material shall be in accordance with this specification, Division 1000, Material Details, and specifically as follows:

Item	Section
Reinforcing Steel for Concrete	1036
Concrete Admixtures	1054
Concrete Curing Material	1055
Mortars and Grout	1066
Water	1070

**701.3.1 Concrete.** Drilled shafts shall be constructed of Class B-2 concrete, and all material, proportioning, mixing and transporting of concrete shall be in accordance with [Sec 501](#), except as specified herein. An air entrainment admixture shall be used. A high range water-reducing admixture may be used to increase the slump to a maximum of 8 inches (200 mm). If used, the water-reducing admixture shall be added only after the concrete has reached the job site to reduce the potential for flash setting. The concrete mix for drilled shafts shall be dense, homogeneous, fluid and resistant to segregation, and shall consolidate under self-weight. The concrete mix shall have a set time that ensures that fluidity is maintained throughout the shaft concrete placement and removal of temporary casing, if used. A concrete retarder in accordance with AASHTO M 194, Type B, may be incorporated into the mix to retard set approximately two hours. Concrete for drilled shafts shall have a 28-day minimum

compressive strength of 4000 psi (28 MPa). Portland cement shall be Type I or Type II. The maximum water per cement ratio of a concrete mix to be placed under water shall be 0.45.

**701.3.2 Casing.** Welded or seamless steel permanent casings shall be in accordance with ASTM A 252, Grade 2, unless otherwise specified. The contractor shall furnish two copies of certification from the fabricator detailing the designated specification with which the furnished casings comply.

**701.3.2.1 Shop Drawings.** Shop drawings for permanent steel casings shall be prepared in accordance with [Sec 1080](#) and shall be submitted to the engineer prior to installation of the casings.

**701.3.2.2 Condition of Casings.** Casings shall be smooth, clean and watertight. For out-of-round tolerance of steel casings before and after installation, the departure of any point on the periphery of the casing from a true circle shall not exceed one inch (25 mm), measured radially.

**701.3.2.3 Extent of Casing Length.** Permanent casings, if required, shall be continuous wherever possible or practical. The permanent casing shall terminate at the specified elevation, and the concrete shall be trimmed to within tolerances specified in [Sec 701.4.16](#) prior to acceptance of the completed drilled shaft. Permanent casings shall be extended into rock, as needed, to provide a positive seal and to stabilize the shaft excavation against collapse, excessive deformation, or flow of water. Casings meeting all specified requirements shall be installed from the work platform to the elevations shown on the plans. Where drilled shafts are located in open water areas, casings shall be extended from at least 18 inches (450 mm) above the water elevation and unless otherwise specified in the contract documents, to the specified bottom of casing elevation to protect the shaft concrete from water action during placement and curing of concrete.

**701.3.2.4 Use of Teeth or Cutting Edge.** The casing may be fabricated with teeth or a cutting edge to facilitate insertion into the rock.

**701.3.2.5 Splices.** Splicing of permanent casings is not desirable and will only be permitted when approved by the engineer. If splices are required, the welding process shall be in accordance with the requirements specified herein. The contractor shall be fully responsible for the adequacy of welds during driving.

**701.3.2.6 Welding.** Shop welding of casings shall be performed by a fully-automated welding process to develop the full capacity of the shell. All welding shall be in accordance with [Sec 1080](#), except that shop welding of casings will not require radiographic inspection. Inspection will be of a visual nature. If evidence indicating poor welding is found, the engineer may require radiographing. Field-welded splices of sections of the steel casings shall be made by shielded metal-arc welding procedures performed by a MoDOT-certified field welder using properly dried low-hydrogen E7018 electrodes that have been protected from the elements to maintain the dry condition. The welds shall be full penetration, watertight and of x-ray quality in accordance with [Sec 1080](#).

**701.3.3 Slurry.** Drilling slurry will be defined as mineral slurry, polymer slurry, natural slurry formed during the drilling process, water or other fluids used to maintain stability of the drilled shaft excavation to aid in the drilling process or to maintain the quality of the rock socket. In addition, the terms mineral slurry and polymer slurry, as used herein, will be defined as the final mixed composite of all additives, including manufactured mineral or polymer slurry additives required to produce the acceptable drilling slurry.

**701.3.3.1 Slurry Usage.** Drilling slurry shall be used if detailed in the approved installation plan, if in accordance with the contract documents or if approved in writing by the engineer. Drilling slurry may be used at the contractor's option if the slurry is not in accordance with the contract documents; however, any slurry shall be approved by the engineer prior to use. Drilling slurry, when used, will be noncompensable and effect on time of performance due to the use of the slurry will be nonexcusable.

**701.3.3.2 General Properties.** The material used to make the slurry shall not be detrimental to the concrete or surrounding ground strata. Mineral slurries shall have both a mineral grain size that remains in suspension and sufficient viscosity and gel characteristics to transport excavated material to a suitable screening system. Polymer slurries shall have sufficient viscosity and gel characteristics to transport excavated material to suitable screening systems or settling tanks. The percentage and specific gravity of the material used to make the slurry shall be sufficient to maintain the stability of the excavation and to allow proper concrete placement. If approved by the engineer, the contractor may use water and on-site soils as a drilling slurry. In that case, the range of acceptable values for density, viscosity and pH, as shown in the following table for bentonite slurry, shall be met, except that maximum density (unit weight) shall not exceed 70 pounds/cubic foot (1120 kg/m<sup>3</sup>). When water is used as the drilling fluid to construct rock sockets in limestone, dolomite, sandstone or other formations that are not erodible, the requirements for slurry testing will not apply.

**701.3.3.3 Preparation.** Prior to introduction into the shaft excavation, the manufactured mineral or polymer slurry admixture shall be pre-mixed thoroughly with clean, fresh water and for adequate time in accordance with the slurry admixture manufacturer's recommendations allotted for hydration. Water used for mixing shall be in accordance with [Sec 1070](#). Slurry tanks of adequate capacity will be required for slurry mixing, circulation, storage and treatment. No excavated slurry pits will be allowed in lieu of slurry tanks without written approval from the engineer. Adequate desanding equipment will be required as necessary to control slurry properties during the drilled shaft excavation in accordance with the values provided in the table below. Desanding will not be required for signposts or lighting mast foundations unless specified in the contract documents.

**701.3.3.4 Control Tests.** Control tests using a suitable apparatus shall be performed by the contractor on the slurry to determine density, viscosity, sand content and pH of freshly mixed slurry, recycled slurry and slurry in the excavation. Tests of slurry samples from within one foot (0.3 m) of the bottom and at mid-height of the shaft shall be conducted in each shaft excavation during the excavation process to establish a consistent working pattern. A minimum of four sets of tests shall be conducted during the first eight hours of slurry use on the project. When the results show consistent behavior, the testing frequency may be decreased to one set every four hours of slurry use, or as otherwise approved by the engineer. Reports of all tests, signed by an authorized representative of the contractor, shall be furnished to the engineer on completion of each drilled shaft. An acceptance range of values for the physical properties will be as shown in the table below.

**701.3.3.5 Sampling.** When slurry samples are found to be unacceptable, the contractor shall bring the slurry in the shaft excavation to within specification requirements. Concrete shall not be poured until resampling and testing results produce acceptable values. Prior to placing shaft concrete, the contractor shall take slurry samples from within one foot (0.3 m) of the bottom and at mid-height of the shaft. Any heavily contaminated slurry that has accumulated at the bottom of the shaft shall be removed. Disposal of all slurry shall be done in areas approved by the engineer. The contractor shall perform final shaft bottom cleaning after suspended solids have settled from the slurry mix.

<b>Range of Acceptable Values for Mineral and Polymer Slurries in Fresh Water Without Additives</b>					
Property	Bentonite	Emulsified Polymer	Dry Polymer	Units	Test Method
<b>Density (Unit Weight)</b>					
At Introduction	63.5 - 66.8 (1017-1070)	< 63 (1009)	< 63 (1009)	lb/ft <sup>3</sup> (kg/m <sup>3</sup> )	Density Balance
Prior to Concreting	63.5 - 70.5 (1017-1129)	< 63 (1009)	< 63 (1009)		
<b>Marsh Funnel Viscosity</b>					
At Introduction	32 – 60 (34 – 63)	33 – 43 <sup>b</sup> (35 – 45) <sup>b</sup>	50 – 80 <sup>b</sup> (53 – 85) <sup>b</sup>	sec/qt (sec/liter)	Marsh Funnel
Prior to Concreting	32 – 60 (34 – 63)	33 – 43 <sup>b</sup> (35 – 45) <sup>b</sup>	50 – 80 <sup>b</sup> (53 – 85) <sup>b</sup>		
<b>pH</b>					
At Introduction	8 – 10	8 – 11	7 – 11	--	pH Paper or pH Meter
Prior to Concreting	8 – 10	8 – 11	7 – 11	--	
<b>Sand Content</b>					
At Introduction	< 4	< 1	< 1	Percent by Volume	API Sand Content Kit
Prior to Concreting	< 10	< 1	< 1		
<b>Maximum Contact Time<sup>a</sup></b>	4	72	72	Hours	

<sup>a</sup>Without agitation and sidewall cleaning.

<sup>b</sup>Higher viscosities may be required to maintain excavation stability in loose or gravelly sand deposits.

#### **701.4 Construction.**

**701.4.1 Protection of Existing Structures.** All precautions shall be taken to prevent damage to existing structures and utilities. These measures shall include, but are not limited to, monitoring and controlling the vibrations from the driving of casing or drilling of the shaft, and selecting construction methods and procedures that shall prevent excessive caving of the shaft excavation.

**701.4.2 Technique Shafts.** When required by the contract documents, the contractor shall demonstrate the adequacy of methods and equipment used during construction of the first drilled shaft, which shall be an out of position technique shaft, constructed with reinforcement as identified for production shafts on the plans. This technique shaft shall be drilled in the position as directed by the engineer and drilled to the maximum depth for any production shaft shown on the plans. If at any time the contractor is unable to demonstrate, to the satisfaction of the engineer, the adequacy of methods or equipment and alterations required, an additional technique shaft(s) may be required. Technique shafts shall be cut off 3 feet (0.9 m) below groundline, buried or otherwise disposed of as specified in the contract documents or as directed by the engineer. Once approval has been given to construct production shafts, no changes will be permitted in the methods of equipment used to construct the shaft without approval from the engineer. When a technique shaft is not required, construction of the first production shaft will be used to determine if the methods and equipment used by the contractor are acceptable. Failure at any time to demonstrate to the engineer the adequacy of methods or equipment will be cause for the engineer to require appropriate alterations in equipment or method by the contractor to eliminate unsatisfactory results.

**701.4.3 Construction Sequence.** Excavation to footing elevation shall be completed before shaft construction begins, unless otherwise authorized by the engineer. Any disturbance to the footing area caused by shaft installation shall be repaired by the contractor prior to pouring the footing. When drilled shafts are to be installed in conjunction with embankment placement, the contractor shall construct drilled shafts after placement of fills. Drilled shafts constructed prior to the completion of fills shall not be capped until the fills have been placed as near to final grade as possible, leaving only the necessary work room for construction of the caps.

**701.4.4 General Equipment and Methods.** The contractor shall perform excavations through whatever material is encountered to the dimensions and elevations shown on the plans. The contractor's methods and equipment shall be suitable for the intended purpose and for whatever material is encountered.

**701.4.4.1 General Equipment.** The contractor shall provide equipment capable of constructing shafts to a depth equal to the deepest shaft tip elevation shown on the plans plus 15 feet (4.6 m), or as otherwise specified in the contract documents. When a rock socket is identified on the plans at a shaft location, the definition of "shaft tip elevation", for the purposes of this subsection, shall be taken to refer to the bottom of the rock socket.

**701.4.4.2 General Methods.** Excavations required for shafts and rock sockets shall be completed in a continuous operation. The contractor shall be responsible for ensuring the stability of the shaft excavation and the surrounding soil. When obstructions, either expected or unexpected, are encountered, the contractor shall notify the engineer promptly. Either the dry method, wet method, temporary casing method, permanent casing method if specified, or combinations, as necessary, shall be used to produce sound, durable concrete drilled shafts free of defects. The permanent casing method shall be used only when required by the contract documents. Blasting excavation methods will not be permitted. When a rock socket is required, the engineer will be the sole judge as to what constitutes the top of sound rock. The engineer may order in writing additional depths of rock socket below the top of sound rock as considered necessary to improve the foundation. If the top surface of the sound rock is found to be inclined across the width of the shaft, the contractor shall immediately notify the engineer. The contractor shall use an airlift, or other method approved by the engineer, to clean the bottom of the shaft excavation.

**701.4.4.2.1 Dry Construction Method.** The dry construction method shall be used only at sites where the groundwater table and site conditions, generally stiff to hard clays or rock above the water table, are suitable to permit construction of the shaft in a relatively dry excavation and where the sides and bottom of the shaft remain stable without any caving, sloughing or swelling and allow visual inspection prior to concrete placement. The dry method shall consist of drilling the shaft excavation, removing accumulated seepage water and loose material from the excavation and placing the shaft concrete in a relatively dry excavation. The dry construction method shall be used only when shaft excavations, as demonstrated in a technique shaft or first production shaft, have 12 inches (300 mm) per hour or less of seepage.

**701.4.4.2.2 Wet Construction Method.** The wet construction method shall be used at sites where a dry excavation cannot be maintained for placement of the shaft concrete. This method shall consist of drilling the shaft excavation below the water table, keeping the shaft filled with water, natural slurry formed during the drilling process, mineral slurry or polymer slurry to contain seepage and groundwater movement, and to maintain stability of the hole perimeter until excavation to the final depth and placement of the reinforcing cage and concrete has been completed. This procedure will require placing the shaft concrete with either a tremie or concrete pump beginning at the shaft bottom, and displacing the water or slurry as concrete is placed. Temporary partial depth casings near the ground surface shall be provided to aid shaft alignment and position and to prevent sloughing of the top of the shaft

excavation. Where drilled shafts are located in open water areas, shafts shall be constructed by the wet method using casings extending from above the water elevation to the plan casing tip elevation to protect the shaft concrete from water action during placement and curing. The casing shall be installed in a manner that produces a positive seal at the bottom of the casing.

**701.4.4.2.3 Temporary Casing Construction Method.** The temporary casing construction method shall be used at all sites where the stability of the excavated hole or the effects of groundwater cannot be controlled by other means. In this method, the hole shall be advanced through caving material by the wet method in accordance with [Sec 701.4.4.2.2](#). When a formation is reached that is nearly impervious, a casing shall be placed in the hole and sealed. Drilling may proceed by the dry method to the projected depth. The placement of concrete shall proceed by the dry or wet method, except that the casing shall be withdrawn after the concrete is placed. In the event seepage conditions prevent use of the dry method, excavation shall be completed by the wet method. Before and during casing withdrawal, a 5-foot (1.5 m) minimum head of fresh concrete above the bottom of the casing shall be maintained at such a level that fluid trapped behind the casing is displaced upward out of the shaft excavation without mixing with or displacing the shaft concrete. Casing extraction shall be at a slow, uniform rate with the pull in line with the axis of the shaft. Temporary casings shall be removed while the concrete is still workable and the slump of the concrete is between 4 and 8 inches (100 and 200 mm). Vibratory hammers shall not be used for casing installation or removal within 50 feet (15.2 m) of other shafts that have been completed less than 24 hours earlier. The reinforcing cage shall not be damaged or displaced when withdrawing the temporary casing.

**701.4.4.2.4 Permanent Casing Construction Method.** The permanent casing construction method shall be used only when required by the contract documents or authorized by the engineer. The casing shall be continuous between top and bottom elevations shown on the plans. Vibratory hammers shall not be used for casing installation within 50 feet (15.2 m) of shafts that have been completed less than 24 hours earlier.

#### **701.4.5 Slurry.**

**701.4.5.1 Time Limitations.** When bentonite slurry is used, the contractor shall adjust construction operations such that the maximum time that slurry is in contact with the bottom 5 feet (1.5 m) of the shaft, the time from the end of drilling to the beginning of concrete placement, does not exceed four hours without agitation. If the four-hour limit is exceeded, the bottom 5 feet (1.5 m) of the shaft shall be overreamed prior to performing other operations in the shaft. For rock sockets constructed in shale using polymer slurry, concrete placement shall begin within 72 hours of starting the rock socket excavation to avoid degradation of the shaft sidewall. Before concrete placement begins, foundation inspection, when required, cleaning operations and reinforcing steel placement shall be completed and approved by the engineer. These operations will be included in the 72-hour time limit. If concrete placement is not begun within the time limit, the contractor shall take corrective measures to the satisfaction of the engineer.

**701.4.5.2 Level of Slurry.** During construction, the level of slurry shall be maintained at a height sufficient to prevent caving of the excavation. If the engineer determines that the slurry construction method is failing to produce the desired final results, the contractor shall discontinue operations and propose an alternate method for approval from the engineer. Correction for a failed slurry construction method will be noncompensable and any effect on time of performance nonexcusable.

**701.4.5.3 Slurry Manufacturer's Representative.** When manufactured mineral or polymer slurry additives are to be incorporated into the drilling slurry mix, the contractor shall provide the technical assistance of a representative of the mineral or polymer slurry additive

manufacturer at the site prior to introduction of the slurry into the first shaft where slurry use will be required, and during drilling and completion of a minimum of one shaft to adjust the slurry mix to the specific site conditions.

**701.4.5.4 Drilling Fluids for Rock Socket Excavation.** For rock sockets excavated in limestone, dolomite, sandstone or other formations that are not erodible and cannot be constructed in the dry, only water shall be used as the drilling fluid, except that when other slurry types are used in drilling through overburden, that slurry shall be removed and replaced with fresh clean water prior to rock socket excavation. For rock sockets excavated in geomaterial that may be eroded by drilling water, such as shales, a polymer slurry will be required prior to beginning rock socket drilling through completion of concreting the rock socket.

**701.4.6 Cleaning of Shaft or Casing Sidewalls.** Cleaning of the shaft or casing sidewalls shall occur by a method approved by the engineer as necessary to remove the depth of softening or to remove excessive slurry cake buildup.

**701.4.7 General Excavation Considerations.** The plans will indicate the top of shaft elevations and the estimated bottom of shaft elevations between which the drilled shaft shall be constructed. Drilled shafts may be extended deeper when the engineer determines that the foundation material encountered while drilling the shaft excavation is unsuitable or is not the same as anticipated in the design of the drilled shaft. Drilled shafts may be shortened when the engineer determines the material encountered is better than that anticipated, or based on the results of load tests.

**701.4.7.1 Time Restrictions.** The integrity of the drilled shaft excavation shall be maintained by the placing of reinforcement and concrete in a timely manner following completion of the excavation. No two adjacent shafts shall be excavated at the same time, and shafts shall not be constructed within 24 hours of the completion of an adjacent shaft if the center-to-center spacing is less than 3 shaft diameters.

**701.4.7.2 Disposal of Excavated Material.** Excavated material removed from the shaft and any drilling fluids used shall be disposed of in accordance with the contract documents, as directed by the engineer, and in compliance with federal and state laws.

**701.4.7.3 Worker Entry Into Shaft Excavation.** The contractor shall not allow workers to enter the shaft excavation for any reason, unless both a suitable casing has been installed and adequate safety equipment and procedures have been provided to workers entering the excavation.

**701.4.8 Unexpected Obstructions.** Subsurface obstructions at drilled shaft locations shall be removed by the contractor. The contractor shall employ special procedures or tools when the hole cannot be advanced using conventional equipment. Blasting will not be permitted. Except as provided in this section, all cost and time effects, direct, indirect and cumulative of subsurface obstruction of whatever nature, will be conclusively deemed fully compensated under the pay items in accordance with the contract. Encountering unexpected obstructions will be considered inherent risks in the nature of this work, both as to type and extent as is variability in material encountered in the work as to effort required to drill through or excavate the material. In the event the contractor encounters at the site of a drilled shaft location a subsurface or latent physical condition that differs materially from that indicated in the contract documents, the contractor shall strictly follow the procedure provided for a differing site condition set forth in [Sec 104](#). Any adjustment to the contract amount or time will only be those expressly permitted by the contract documents and only to the extent expressly provided in the contract documents. No contract adjustment will be determined, as to entitlement or amount on any basis other than under the contract as a differing site condition. Specifically,

but not by way of limitation, the contractor agrees that the contractor will not be entitled to any contract adjustment arising from encountering an unexpected obstruction on the basis that, with respect to the obstruction, the Commission made: (1) a positive representation; (2) of a material fact; (3) which was false or incorrect; (4) as to which positive representation of material fact the contractor lacked knowledge that the representation was false or incorrect; (5) upon which positive representation of material fact the contractor asserts that the contractor relied; and (6) was damaged as a direct result of the positive representation of material fact.

**701.4.9 Lost Tools.** Drilling tools lost in the excavation will not be considered obstructions and shall be promptly removed by the contractor. All work required to remove lost tools or to perform associated corrective work, including but not limited to repair of hole degradation due to removal operations, will be noncompensable and any effect on time of performance nonexcusable.

#### **701.4.10 Excavation Inspection.**

**701.4.10.1 Inspection Equipment.** The contractor shall maintain at the job at all times, all equipment suitable for use in the shaft inspection.

**701.4.10.2 Removal of Excess Sediment and Water.** Final shaft depth shall be measured with approved methods after final cleaning by airlift, or other method approved by the engineer. Unless otherwise stated in the contract documents, a minimum of 50 percent of the base of each shaft shall have less than 1/2 inch (13 mm) of sediment at the time of concrete placement. The maximum depth of sediment or any debris at any place on the base of the shaft shall not exceed 1 1/2 inches (38 mm). For dry excavations, the maximum depth of water shall not exceed 3 inches (75 mm) prior to concrete pour. Shaft cleanliness will be verified by the engineer for wet or dry shafts.

**701.4.10.3 Television Camera Inspection.** The primary means of inspecting a shaft excavation, steel casing and the rock socket shall be by television camera lowered into the shaft. The contractor shall furnish all equipment necessary to conduct the camera inspection. The contractor shall operate the camera and supporting equipment under the direction of the engineer in such a manner as to obtain optimum results from the equipment. The television camera and lighting equipment shall be capable of operating in dry or submerged conditions encountered during the inspection. The excavated shaft shall have the engineer's approval prior to proceeding with construction.

**701.4.10.3.1 Equipment.** Methods and equipment for controlling the camera will be subject to approval from the engineer and achievement of a satisfactory video record.

**701.4.10.3.2 Drawings.** The contractor shall submit layout drawings to the engineer showing the relative position of all components of the television inspection system, including type and size of barge or other work area. The information submitted shall include a written description of the operating procedure in a step-by-step sequence and shall state the source of power.

**701.4.10.3.3 Shaft Inspection.** Inspection of a shaft by television camera shall be performed as directed by the engineer. The excavated shaft, including the rock socket when applicable, shall be thoroughly cleaned of all loose fragments, sediment and turbidity prior to inspection. The camera shall be operated such that optimum clarity of detail can be obtained and all surface areas of the shaft, including the rock socket and the rock socket's base, can be observed. All scanning of the rock surfaces shall be recorded on videotape. After completion of the inspection of a rock socket, the engineer will direct whether or not drilling of the shaft shall be continued to a greater depth. All tapes shall be stored in proper containers with dust-tight closures and shall be properly labeled as to shaft number along with project and



contractor identification. Tapes shall be furnished to and shall become the property of the engineer upon completion of the work.

**701.4.11 Foundation Inspection.** NX size cores will be required for drilled shafts with rock sockets, where NX refers to the nominal diameter of rock core, and the NX core barrel has a 2 1/8-inch (54 mm) inside diameter. The contractor may be directed to extend the rock socket to a lower elevation, resulting from the engineer's evaluation of the foundation inspection cores.

**701.4.11.1 Inspection for End Bearing Design.** For drilled shafts that develop load-carrying capacity in end bearing at the base of the rock socket, the contractor shall drill one NX size core for each rock socket to a depth of 10 feet (3 m) below the bottom of the rock socket upon completion of the rock socket to the elevation shown on the plans, or as directed by the engineer. This requirement will also apply for rock socket designs that utilize a combination of end bearing and side friction. These rock cores will be used to determine the quality of founding material directly below the rock socket. When a casing method is used, foundation inspection holes may be drilled prior to rock socket excavation, if approved by the engineer. Foundation inspection holes may be drilled prior to shaft excavation if the contractor can establish, to the satisfaction of the engineer, that the method used shall place the NX size core directly below the tip of the rock socket.

**701.4.11.2 Inspection for Side Friction Design.** For drilled shafts that develop load-carrying capacity through side friction only within the rock socket, the contractor shall drill one NX size core for each rock socket at a location directed by the engineer, to a depth of 10 feet (3 m) below the bottom of the rock socket as shown on the plans or as directed by the engineer. These rock cores will be used to determine the quality of material of the rock socket sidewalls. Foundation inspection holes for rock sockets designed to provide side friction shall be drilled prior to rock socket excavation.

**701.4.11.3 Log of Excavated Material.** The contractor shall maintain a log of excavated material for each foundation inspection hole, and such logs shall be delivered to the engineer within 24 hours of completion of the boring. The log shall include the following:

- (a) The amount of NX cored per run and the amount recovered. All core loss shall be noted and explained. Clay layers shall be noted and located on the log by depth.
- (b) The Rock Quality Designation (RQD) for the NX core. The bedding thickness and degree of weathering shall also be noted.
- (c) For drilled shaft rock sockets that develop load-carrying capacity through side friction, one unconfined compression test per 5 feet (1.5 m) of NX core, unless otherwise specified by the contract documents or directed by the engineer, shall be run on samples of NX core from the rock socket. The results of these tests shall be delivered to the engineer. Any effect on time of performance resulting from delays in delivery of the above test results to the engineer will be nonexcusable.

**701.4.11.4 Storage and Labeling of Rock Cores.** Rock cores shall be stored in structurally sound core boxes and shall be protected from the elements. The core boxes shall be properly labeled to indicate location, depth, beginning elevation, contractor and date, and shall be delivered to the engineer.

**701.4.12 Reinforcing Steel Cage Fabrication and Placement.** The reinforcing steel cage, consisting of the longitudinal bars, ties, spirals, cage stiffener bars, spacers, centering devices, and other necessary appurtenances, shall be completely assembled as a unit, and shall be placed immediately after the shaft excavation is inspected and accepted, and just prior to shaft

concrete placement. Temporary internal cage stiffeners shall be removed as the cage is placed in the shaft such that interference with the placement of concrete does not occur.

**701.4.12.1 Reinforcing Ties, Splices and Clearances.** All reinforcing steel in the shaft shall be double-wire tied and supported such that the steel remains within the allowable tolerances specified herein during placement of concrete or casing removal. With approval from the engineer, mechanical bar splices meeting the requirements specified in the contract documents may be used. Mechanical bar splices shall be staggered such that no more than 50 percent of the splices are within a 2-lap splice distance. Welding of reinforcing steel will not be permitted. The reinforcing steel cage shall have sufficient rigidity to prevent racking or permanent deformations during delivery or installation.

Concrete Cover			
Shaft Diameter	Uncased	Casing Remains	Casing Withdrawn
2'-0" or less (600 mm or less)	3" (75 mm)	3" (75 mm)	4" (100 mm)
3'-0" (900 mm)	3" (75 mm)	3" (75 mm)	4" (100 mm)
4'-0" (1200 mm)	4" (100 mm)	4" (100 mm)	4" (100 mm)
5'-0" or larger (1500 mm or larger)	6" (150 mm)	6" (150 mm)	6" (150 mm)

**701.4.12.2 Spacers.** Rolling spacers for reinforcing steel shall be used to minimize disturbance of the shaft sidewalls and to facilitate removal of the casing during concrete placement. Concrete spacers or other approved non-corrosive spacing devices shall be used at sufficient intervals, near the bottom and along the shaft at intervals not exceeding 5 feet (1.5 m), to ensure concentric location of the cage within the shaft excavation. When the vertical steel is greater than one inch (25 mm) in diameter, the maximum spacing may be increased to 10 feet (3.0 m). As a minimum, a set of spacers shall be provided within 2 feet (0.6 m) of both the top and bottom of the shaft. In addition, one set of spacers shall be provided at both 2 feet (0.6 m) above and below each change in shaft diameter. Non-corrosive spacers shall be provided at a minimum of one spacer per 30 inches (750 mm) of circumference of cage with a minimum of three at each level to maintain the required reinforcement clearances. The spacers shall be of adequate dimension to maintain the specified clearance between the outside of the reinforcing cage and the side of the excavated hole or casing.

**701.4.12.3 Bottom Supports.** Approved non-corrosive bottom supports shall be provided for the reinforcing cage to ensure that the reinforcing is the correct distance above the bottom of shaft. The bottom supports shall not be used to support the weight of the cage. In the event that the shaft has been excavated below the anticipated tip elevation, the reinforcing cage shall be extended at the lower tip end by lap lengths for No. 11 bars or smaller or by use of mechanical connectors. Splices of adjacent bars will not need to be staggered in this situation and all of the reinforcing bars may be spliced at a given location. Reinforcement will not be required for the bottom 12 inches (300 mm).

**701.4.12.4 Durability of Spacers.** Concrete spacers and bottom supports shall be constructed of concrete equal in quality and durability to the concrete specified for the shaft. Spacers fabricated from reinforcing steel shall be epoxy coated.

**701.4.12.5 Protection of Reinforcing Cage.** The reinforcing cage bottom supports shall be positioned such that the reinforcing steel is not allowed to come into contact with the soil or rock and to ensure that the bottom of the cage is maintained at the proper distance above the base as identified in the contract documents or directed by the engineer.

**701.4.12.6 Check of Tolerances for Placement of Reinforcing Cage.** The elevation of the top of the reinforcing cage shall be checked before and after the concrete is placed. The reinforcing cage shall be maintained within the specified tolerances, and the contractor shall make corrections to those tolerances, as required, to the satisfaction of the engineer. No additional shafts shall be constructed until the contractor has modified the reinforcing cage support to obtain the required tolerances.

#### **701.4.13 Concrete Placement.**

**701.4.13.1 General Considerations.** Accumulations of water in casings and excess sediment at the base shall be removed as described herein before the concrete is placed. No concrete shall be placed until all casings, if used, within a 15-foot (4.6 m) radius have been installed. Within the 15-foot (4.6 m) radius, all driving or vibratory installation methods shall be discontinued until the concrete in the last shaft has set at least five days. Concrete placement shall begin as soon as possible after completion of the excavation, inspection and setting of the reinforcing cage, and shall proceed in a continuous operation from the bottom of the shaft to the plan construction joint or above as specified herein. An unplanned stoppage of work may require an emergency construction joint during the shaft construction.

**701.4.13.1.1 Placement of Concrete in the Shaft.** Concrete shall be placed for each shaft with the flow of concrete directed down the center of the shaft. Concrete shall be placed by free fall or through a tremie or concrete pump. The free fall placement method will only be permitted in dry holes when approved by the engineer. The maximum height of free fall placement shall be 80 feet (24.4 m). Concrete placed by free fall shall fall directly to the base without contacting either the reinforcing cage or hole sidewall. Drop chutes may be used to direct concrete to the base during free fall placement.

**701.4.13.1.2 Extent of Concrete Placement.** Concrete placement shall continue after the shaft is filled until good quality concrete, as determined by the engineer, is evident at the plan construction joint at the top of the shaft and until a minimum of 18 inches (450 mm) of concrete, measured vertically, has been expelled. Immediately after concrete placement has been completed, all contaminated concrete and deleterious material accumulated above the top of shaft shall be removed to within one foot (0.3 m) of plan top of shaft. Any concrete remaining above the top of shaft shall be carefully removed to the plan construction joint after curing and excess casing removal.

**701.4.13.1.3 Time Limitations.** The elapsed time from the beginning of concrete placement in the shaft to the completion of the placement shall not exceed two hours. All admixtures shall be adjusted for the conditions encountered on the job so the concrete remains in a workable plastic state throughout the two-hour placement limit. 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 the two-hour requirement. The contractor may request a longer placement time if a concrete mix is provided that will maintain a slump of 4 inches (100 mm) or greater over the longer placement time in the entire shaft as demonstrated by trial mix and slump loss tests. The trial mix and slump loss tests shall be conducted using concrete and ambient temperatures approved for site conditions.

**701.4.13.1.4 Adequacy of Concrete Placement Method.** Failure to demonstrate the adequacy of concrete placement methods or equipment during construction of any technique or production shafts will be cause for the engineer to require appropriate alterations in equipment or methods by the contractor to eliminate unsatisfactory results. Drilled shafts that are completed, but do not meet the concrete placement requirements, will be unacceptable.

The contractor shall correct all unacceptable completed shafts to the satisfaction of the engineer at the contractor's expense.

**701.4.13.2 Concrete Placement by Tremie.** Tremies used to place concrete shall consist of a tube of sufficient length to discharge concrete at the shaft base elevation. The tremie shall have sufficient weight to rest on the shaft bottom before the start of concrete placement and to prevent curling of the tremie line during placement of the concrete. The tremie shall not contain aluminum parts that may come in contact with the concrete. A tremie shall consist of a watertight tube having an inside diameter of no less than 10 inches (250 mm) and fitted with a hopper at the top. The inside and outside surfaces of the tremie shall be clean and smooth to permit both flow of concrete and unimpeded withdrawal during concrete placement. The tremie wall thickness shall be adequate to prevent crimping or sharp bends that restrict concrete placement. Tremies used for depositing concrete in a dry drilled shaft excavation shall be supported such that the free fall of the concrete is less than 80 feet (24.4 m) at all times.

**701.4.13.2.1 Adjustment of Concrete Free Fall or Rate of Concrete Flow.** If the free fall concrete causes the shaft excavation to cave or slough, the contractor shall control the movement of concrete by reducing the free fall of the concrete or the rate of flow of concrete into the excavation. The contractor shall be responsible for proposing, developing, and after approval from the engineer, implementing corrective work.

**701.4.13.2.2 Tremie Operation.** Underwater placement of concrete shall not begin until the tremie is at the shaft base elevation. The discharge end of the tremie shall be constructed to permit the free radial flow of concrete during placement operations. The tremie discharge end shall remain immersed as deep as practical in the concrete, but shall be no less than 5 feet (1.5 m) at all times. The tremie shall be supported such as to permit free movement of the discharge end over the entire top surface of the work and to permit rapid lowering when necessary to retard or stop the flow of concrete. The discharge end shall be sealed closed at the start of work to prevent water from entering the tube before the tube is filled with concrete. After placement has started, the level of the concrete in the tremie shall be maintained above the level of slurry or water in the borehole at all times to prevent water or slurry intrusion into the shaft concrete. If water enters the tube after placement is started, the tremie shall be withdrawn, the discharge end resealed, and the placement restarted. The flow of concrete shall be continuous until the work is completed.

**701.4.13.2.3 Removal of Tremie Orifice From Concrete.** If at any time during the concrete pour, when using the wet construction method, the tremie line orifice is removed from the fluid concrete column and discharges concrete above the rising concrete surface, the entire drilled shaft will be considered defective. In such a case, the contractor shall remove the reinforcing cage and concrete, complete any necessary sidewall cleaning or overreaming as directed by the engineer, and repour the shaft. Corrections made by the contractor will be noncompensable and any effect on time of performance nonexcusable.

**701.4.13.3 Concrete Placement by Pump.** Concrete pumps and lines may be used for concrete placement by either the wet or dry construction method. All pump lines shall have a minimum diameter of 5 inches (125 mm) and shall be constructed with watertight joints. Concrete placement shall not begin until the pump line discharge orifice is at the shaft base elevation. For the wet construction method, a plug or similar device shall be used to separate the concrete from the fluid in the hole until pumping begins. The plug shall either be removed from the excavation or shall be of a material that does not cause a defect in the shaft if the plug is not removed. The discharge orifice shall remain at least 5 feet (1.5 m) below the surface of the fluid concrete. If at any time during the concrete pour the pump line orifice is removed from the fluid concrete column and discharges concrete above the rising concrete level, the shaft will be considered defective. In such a case, the contractor shall remove the reinforcing

cage and concrete, complete any necessary sidewall cleaning or overreaming as directed by the engineer, and repour the shaft. Corrections made by the contractor will be noncompensable and any effect on time of performance nonexcusable.

**701.4.13.4 Drop Chutes.** Drop chutes may be used to direct placement of free fall concrete down the center of the shaft excavations where the maximum depth of water does not exceed one inch (25 mm). The free fall method of placement shall not be used in wet excavations. Drop chutes shall be a smooth tube constructed either as a continuous one-piece unit or as removable sections. Aluminum drop chutes will not be permitted. Concrete may be placed through either a hopper at the top of the tube or side openings as the drop chute is retrieved during concrete placement. The drop chute shall be supported such that the free fall of the concrete measured from the bottom of the chute is less than 80 feet (24.4 m) at all times.

**701.4.14 Construction Joints.** Unless otherwise approved by the engineer, construction joints shall be made only where shown on the plans. All planned reinforcing steel shall extend uninterrupted through joints. Unless otherwise shown on the plans, horizontal joints may be constructed without keys. Surfaces of fresh concrete at horizontal construction joints shall be rough floated sufficiently to thoroughly consolidate the surface and to intentionally leave the surface in a roughened condition. Shear keys, if required, shall consist of formed depressions in the surface covering approximately one-third of the contact surface.

**701.4.15 Concrete Protection and Curing.** For at least 48 hours after shaft concrete has been placed, no construction operations that will cause soil movement adjacent to the shaft shall be conducted, except for movement of light construction equipment. Portions of drilled shafts exposed to a body of water shall be protected from the action of water by leaving the forms in place for at least seven days after concrete placement or until the shaft concrete reaches a minimum strength of 2500 psi (18 MPa). After placement, the temporarily exposed surfaces of the shaft concrete shall be cured to prevent loss of water by use of one or more of the approved methods. Curing shall be in accordance with [Sec 502](#).

**701.4.16 Construction Tolerances.** During excavation of the shaft, the contractor shall make frequent checks on the plumbness, alignment and dimensions of the shaft. Any deviation exceeding the allowable construction tolerances specified herein shall be corrected with a procedure approved by the engineer. Drilled shaft excavations constructed in such a manner that the concrete shaft cannot be completed within the required tolerances will not be accepted. Correction methods shall be submitted by the contractor for the engineer's approval. Drilled shaft construction shall not begin until approval has been obtained. When a shaft excavation is completed with unacceptable tolerances, the contractor shall propose, develop and, after approval from the engineer, implement corrective work. Redesign drawings and computations submitted by the contractor shall be signed by a professional engineer registered to practice in the State of Missouri. The following construction tolerances will apply to drilled shafts unless stated otherwise in the contract documents:

(a) Temporary casing diameters shall provide a final shaft diameter as shown on the plans. When approved by the engineer, the contractor may provide a larger casing at the contractor's expense.

(b) Shafts shall be constructed such that the center of the top of the shaft is within 3 inches (75 mm) of plan position in the horizontal plane at the plan elevation for the top of the shaft.

(c) The vertical alignment of a vertical shaft excavation shall not vary from the plan alignment by more than 1/4 inch per foot (20 mm/m) of depth. The alignment of a battered shaft excavation shall not vary by more than 1/2 inch per foot (40 mm/m) of the distance along the axis of the shaft from the prescribed batter.

(d) After all the shaft concrete is placed, the top of the reinforcing steel cage shall be no more than 6 inches (150 mm) above and no more than 3 inches (75 mm) below plan position.

(e) The top elevation of the shaft shall be no more than one inch (25 mm) above or 3 inches (75 mm) below the plan top of shaft elevation.

(f) The bottom of the shaft excavation shall be normal to the axis of the shaft within a tolerance of 3/8 inch per foot (30 mm/m) of shaft diameter.

**701.4.17 Integrity Testing.** The completed shaft shall be subjected to the specified testing methods, such as concrete coring or sonic logging testing, to determine the extent of any defects that may be present. Work and material required for testing shall be furnished by the contractor and will be paid for in accordance with the contract documents. If testing reveals voids or discontinuities in the concrete that, as determined by the engineer, indicate that the shaft is not structurally adequate, the shaft will be rejected. The contractor shall then repair, replace or supplement the defective shaft in a method approved by the engineer. The construction of additional drilled shafts shall be discontinued until the contractor demonstrates the adequacy of the shaft construction method to the satisfaction of the engineer. Any additional work required by the contractor as a result of shaft defects will be noncompensable and any effect on time of performance nonexcusable.

**701.4.17.1 Concrete Coring.** At locations where concrete coring is to be provided, as indicated in the contract documents or as directed by the engineer, the following will apply. Upon completion of placing concrete and after waiting a minimum of 48 hours, the top surface of concrete shall be cleaned of laitance and any unsound concrete, and then one core hole shall be drilled completely through the shaft concrete and the rock socket to approximately one foot (0.3 m) below the bottom of the rock socket of each shaft. Provisions for the inspection of the concrete surface shall be in accordance with the applicable requirements described herein. Core holes shall be drilled at locations specified by the engineer. The holes shall be drilled to recover NX size cores. The core samples recovered shall be labeled as to the location from which the samples were taken. The samples shall be delivered to the engineer for examination. If the cores indicate defective concrete in the shaft, which in the judgment of the engineer impairs the strength of the completed shaft, the contractor shall drill additional cores as directed by the engineer. If the concrete is found to be defective, the contractor shall submit to the engineer in writing a proposal for correction, and those corrective procedures shall be approved by the engineer before such corrective work is undertaken. The cored holes in non-defective concrete shall be filled with grout such that all voids are filled. All grout used for core holes shall be in accordance with [Sec 1066](#). No direct payment will be made for grout and grouting.

**701.4.17.2 Sonic Logging Testing.** The contractor shall perform non-destructive integrity testing on completed drilled shafts and rock sockets using the crosshole sonic logging (CSL) method for concrete drilled shafts. The tests shall be conducted as indicated on the plans or other contract documents, or as directed by the engineer. Sonic logging measurements and data interpretation shall be performed by a CSL consultant with at least two years of experience in CSL drilled shaft testing. The contractor shall submit the testing organization experience record to the engineer, along with a written description of the testing procedures, operation manuals for the testing equipment, and samples of previous test results indicating both sound and defective concrete. The contractor shall inform the engineer of scheduled test dates at least seven days prior to CSL testing. The contractor shall provide reasonable access to the shaft top for performance of the sonic logging testing.

**701.4.17.2.1 Installation of Pipes.** The contractor shall furnish and install 2-inch (50 mm) nominal inside diameter steel pipes, ASTM A 53, Standard Weight, for use in sonic testing of each drilled shaft. Pipes shall be installed in each drilled shaft at the locations shown on the plans, as required by the testing agency or as directed by the engineer. The pipes shall be sufficiently regular and free from defects to permit the free and unobstructed passage of the probes. The pipe shall be installed such that all internal joints are flush. Stiffening devices such as mandrels, tape or similar material to seal the joints shall not be used. Pipe shall be watertight with clean internal and external faces, the latter to ensure a good bond between the concrete and the pipes. The pipes shall be fitted with a screw-on watertight shoe and cap and shall be securely fixed to the interior of the reinforcement cage with a minimum cover of 3 inches (75 mm) from the shaft periphery. The pipes shall be as near to parallel as possible, equally spaced and vertical. Where several sections of pipe are required to reach the full length, joints shall be made watertight. The pipes shall be filled with water and plugged or capped before shaft concrete is poured. The upper end of the pipe shall not be left open after the pour. The pipes shall extend at least 3 feet (0.9 m) above the top of the concrete in the shaft to compensate for water displaced by insertion and removal of the transmitter, receiver, and cable. For shafts with a rock socket, the lower end of the pipes shall extend to the bottom of the rock socket. Care shall be taken during the drilled shaft concrete pour to not damage the pipes. If a tremie is used, the tremie shall not be permitted to rest on top of the pipes during the pour. After completion of the sonic logging and final acceptance of the drilled shaft, the contractor shall fill the access pipes with grout.

**701.4.17.2.2 Sonic Logging Equipment.** The sonic logging equipment furnished by the CSL consultant shall consist of all necessary supplies, support equipment and power to perform the sonic logging testing requirements as described herein.

**701.4.17.2.3 Sonic Logging Test Procedure.** The drilled shaft shall be tested between 2 and 40 days after concrete placement. The following procedures shall apply:

- (a) Pipes shall be checked to ensure the pipes are free from blockages and are filled with water.
- (b) Levels shall be taken on top of each pipe, each pipe shall be plumbed and the length shall be recorded.
- (c) Testing shall be performed between each pair of adjacent pipes around the shaft perimeter and also in pairing combinations between each pipe with all other pipes in the shaft.
- (d) All tests shall be carried out with the probes in the same horizontal plane unless the engineer directs that defects be further evaluated with the probes on different horizontal planes.
- (e) The probes shall be raised simultaneously from the bottom of the pipes ensuring that all slack is taken out of the cables before the analyzer is switched on, and that the distance between transducers remains constant during the course of the test. The speed of ascent shall be less than 12 inches per second (300 mm/second). Measurements shall be taken at 3-inch (75 mm) intervals or less. Anomalies indicated by longer pulse first-arrival times (FAT) and significantly lower amplitude per energy signals shall be reported. If anomalies are detected, additional tests with two or more sources per receiver vertical offsets of greater than or equal to 20 inches (500 mm) shall be conducted between the same tubes unless the anomaly is within 20 inches (500 mm) of the bottom of the shaft.
- (f) The contractor shall provide accurate measurements of probe depths on the logs.

**701.4.17.2.4 Record of Testing.** Preliminary results of the testing shall be provided on site prior to the CSL consultant leaving the site. A detailed CSL report and test data shall be submitted to the engineer within seven days. The CSL report shall be signed and sealed by a Professional Engineer. The CSL report shall include, but is not limited to, the following: project identification and dates of testing, a table and schematic showing shafts tested with accurate identification of tube coordinates and collar elevation, name of personnel that performed the tests and interpretation and those personnel's affiliation, equipment used, data logs, interpretation, analysis, and results. The data logs shall include XY plots of FAT, amplitude and velocity versus depth. CSL data shall be processed to provide easy to understand 2D cross-sections between tubes for all tube pair combinations. These plots shall be annotated by the CSL consultant as appropriate to delineate anomalous results. If offset surveys are performed as part of 3D tomography, data plots shall include 3D volumetric images for the entire shaft, color-coded, to indicate velocity variations along the shaft. Locations and geometry of anomalies or unconsolidated zones shall be identified in 3D color images with detailed discussion. The results for CSL and 3D surveys shall be based on the percentage decrease in velocity as correlated to the following Concrete Condition Rating Criteria (CCRC). The velocity datum of good concrete shall be established by averaging the velocities in the good concrete along the drilled shaft. Deviations from the velocity datum shall be used for determining the Concrete Condition Rating.

<b>Concrete Condition Rating Criteria</b>			
<b>Concrete Condition Rating</b>	<b>Rating Symbol</b>	<b>Velocity Reduction</b>	<b>Indicative Results</b>
Good	G	0 to 10%	Acceptable concrete
Questionable	Q	10% to 25%	Minor concrete contamination or intrusion. Questionable quality concrete.
Poor	P/D	> 25%	Defects exist, possible water slurry contamination, soil intrusion, and or poor quality concrete.
Water	W	V= 4760 to 5005 ft/sec (1,450 to 1525 m/s)	Water intrusion, or water filled gravel intrusion with few or no fines present.
No Signal	NS	No signal received	Soil intrusion or other severe defect absorbed the signal, tube debonding if near top.

**701.4.17.2.5 Correction of Unacceptable Results.** The contractor shall immediately inform the engineer of any suspected anomalies, honeycombing or poor concrete quality detected by testing. The contractor and CSL consultant shall duly perform further tests as directed by the engineer to evaluate the extent of any detected anomalies. Core drilling, or other investigative methods as approved by the engineer, shall be performed to further investigate the anomaly. If a defect is confirmed, the contractor shall bear all costs involved with the shaft coring, grouting and remediation. Within 14 days of the completion of testing, the contractor shall provide a report signed and sealed by a Professional Engineer registered in the State of Missouri providing the results of the additional investigations and recommendations to accept or repair the shaft. The report shall also contain recommendations for modification of construction procedures to prevent defects for subsequent shaft installations. The dates of the completion of drilling, cleaning, steel placement and concrete pour shall also be provided. Construction above the top of shaft shall not be performed until the shaft has been accepted by the engineer.

**701.5 Drilled Shaft Load Tests.** All load tests, when required by the contract documents, shall be completed and submitted to the engineer for review and approval before construction



of any production drilled shafts. The locations of load test shafts, the maximum loads to be applied, the test equipment to be furnished by the contractor, and the actual sequence of the load testing shall be as shown on the plans or as specified in the contract documents. After completion of testing, test shafts not used as production shafts shall be cut off at an elevation 3 feet (0.9 m) below the finished ground line. The portion of shafts cut off shall be disposed of by the contractor, at the contractor's expense, in a manner approved by the engineer.

#### **701.6 Method of Measurement.**

**701.6.1 Drilled Shaft.** Accepted drilled shafts will be measured for payment to the nearest 0.10 linear foot (0.05 m) of length along the axis of each shaft complete-in-place. For shafts without a rock socket, measurement will be from the plan top of the shaft elevation to the bottom of the shaft. For shafts with a rock socket, measurement will be from the plan top of the shaft to the top of the rock socket. "Top of the rock socket" will be defined as the upper elevation at which sound rock occurs across the entire width of the shaft, as determined by the engineer. Reinforcing steel will be measured for payment in accordance with [Sec 706](#).

**701.6.2 Rock Socket.** The accepted rock sockets, if required, will be measured for payment to the nearest 0.10 linear foot (0.05 m) of length along the axis of each rock socket in-place from the top of sound rock elevation, as determined by the engineer and in accordance with [Sec 701.6.1](#), to the bottom of the rock socket as built. In the event that additional rock socket construction is directed by the engineer, the additional length will be measured to the nearest 0.10 linear foot (0.05 m). Reinforcing steel will be measured for payment in accordance with [Sec 706](#).

**701.6.3 Technique Shafts.** Accepted technique shafts, if required, will be measured for payment to the nearest 0.10 linear foot (0.05 m) of length along the axis of each shaft in-place from the plan top of the shaft elevation to the bottom of the rock socket or shaft as built for each size of acceptable technique shaft drilled, including rock socket. Reinforcing steel will be measured for payment in accordance with [Sec 706](#).

**701.6.4 Television Camera Inspection.** Payment for one complete television camera inspection of each shaft, including the rock socket when applicable, will be included in the payment for drilled shafts. Any additional television inspections required by the engineer due to extending the rock socket to a greater depth or when supplementary inspections are required by the engineer and no defects are found, will be measured for payment as supplementary television camera inspection, per each.

**701.6.5 Foundation Inspection Holes.** Measurement for payment for foundation inspection holes will be to the nearest 0.10 linear foot (0.05 m) of length along the axis of each hole by the linear foot (m). For shafts designed in side friction, measurement will be from the top of the rock socket to the bottom of the foundation inspection hole. For shafts designed in end bearing, measurement will be from the bottom of the rock socket to the bottom of the foundation inspection hole. If the engineer directs foundation inspection borings more than 10 feet (3.0 m) below the anticipated bottom of the rock socket elevation as shown on the plans, measurement for payment for that portion of the boring in excess of 10 feet (3.0 m) below anticipated bottom of the rock socket elevation as shown on the plans will be to the nearest 0.10 linear foot (0.05 m) of excess.

**701.6.6 Concrete Coring.** Measurement for payment for concrete cores will be to the nearest 0.10 linear foot (0.05 m) of length along the axis of the shaft from the top of concrete to a point as determined by the engineer, and may extend the entire length of the shaft plus one foot (300 mm) below the bottom of the rock socket.

**701.6.7 Sonic Logging Testing.** Sonic logging testing of drilled shafts, as required, will be measured for payment per each.

**701.6.8 Drilled Shaft Load Tests.** Load tests will be measured for payment per each load test performed.

**701.7 Basis of Payment.**

**701.7.1 Drilled Shaft.** Payment will be considered full compensation for all steel casing required, costs of drilling, excavation, slurry, cleaning, an acceptable method of inspection as required, furnishing and placing concrete, grouting and incidental work and material required by the contract documents. Payment for any drilled shaft installed and accepted will be at the contract unit price per linear foot (m) for the diameter of the drilled shafts specified, irrespective of the character of the material actually encountered during excavation. No additional compensation will be made for concrete required to fill an oversized casing or for oversized excavation. If the method of construction requires that drilled shaft casing be seated into the sound rock such that the bottom of the casing is below the determined top of sound rock elevation, payment for excavation below the top of the sound rock layer (top of the rock socket) will be included in the payment for the rock socket. If sound rock is encountered within the excavation at which point a rock auger, core barrel or other rock-removing specialty tool must be used by the contractor before the top of the sound rock elevation to be used as “top of the rock socket” is confirmed by the engineer, that work will be paid for as rock socket excavation. Payment for reinforcing steel will be in accordance with [Sec 706](#).

**701.7.2 Rock Socket.** Payment will be considered full compensation for drilling, excavation, slurry, cleaning, dewatering, an acceptable method of inspection as required, furnishing and placing concrete, and incidental work and material according to the contract documents. For payment purposes the length of any rock socket installed and accepted shall be paid for at the contract unit price per linear foot (m) for the diameter of the rock socket specified, irrespective of the character of the material actually encountered during excavation. In the event that the engineer orders additional rock socket construction, payment for the additional length will be at the rate of 150 percent of the contract unit price per linear foot (m) of rock socket up to a maximum additional length of 8 feet (2 m). Any work necessary to extend the length of the rock socket more than the additional 8 feet (2 m) will be paid for as changes in the work in accordance with [Sec 104.3](#). Payment at the adjusted rate will be considered full compensation for the additional excavation into rock, all additional concrete, except reinforcing steel, including any and all splices, and all incidentals necessary to complete the work down to the elevation designated by the engineer. Reinforcing steel will be paid for in accordance with [Sec 706](#).

**701.7.3 Technique Shafts.** Payment for technique shafts will be in accordance with the contract unit prices for the appropriate drilled shaft and rock socket diameters. Payment will be considered full compensation for any steel casing required, all costs of drilling, excavation, an acceptable method of inspection as required, furnishing and placing concrete, grouting and incidental work, and material necessary to satisfactorily construct the technique shafts according to the contract documents. Reinforcing steel will be paid for in accordance with [Sec 706](#).

**701.7.4 Unexpected Obstructions.** Contract adjustment, in time or amount, resulting from encountering any obstructions in the work covered by [Sec 701](#) will be made only if the obstruction constitutes a differing site condition, as defined by the contract. Contract adjustments will be determined only under the terms of the contract for adjustments in time or compensation due to encountering a differing site condition. Contract adjustments will be allowed only to the extent, in type and amount of contract adjustment, that such adjustment is expressly allowed for or permitted by the contract documents, specifically: (1) [Secs 109.4](#)

through 109.4.3 for cost adjustment; (2) Sec 109.11 for any compensable delay to the work to deal with the obstruction, but not for any effect upon the unchanged work; and (3) Sec 108.14 to determine any adjustment in contract time.

**701.7.5 Television Camera Inspection.** Payment for one complete television camera inspection of each shaft, including the rock socket when applicable, will be included in the payment for drilled shafts. Any additional television inspections required by the engineer due to extending the rock socket to a greater depth, or when supplementary inspections are required by the engineer and no defects are found, will be paid for at the contract unit price for supplementary television camera inspection, per each. Payment will not be made for supplementary television camera inspections that reveal defects due to the contractor's operation. Payment for television camera inspection will be considered full compensation for moving in equipment, flushing turbid water from the shaft, conducting the actual scanning as specified, furnishing video tape, removing equipment, and all tools, labor and any incidentals necessary to complete the work. The number of supplementary television camera inspections may vary from the estimated quantities, but the contract unit price shall prevail regardless of the variation.

**701.7.6 Foundation Inspection Holes.** Payment for foundation inspection holes will be at the contract unit price and will be considered full compensation for drilling or coring the holes, extracting and packaging the samples or cores, laboratory testing, delivering the samples or cores to the specified MoDOT location and for all other expenses necessary to complete the work. If the engineer directs foundation inspection borings more than 10 feet (3 m) below the anticipated bottom of rock socket elevation as shown on the plans, payment for that portion of the boring in excess of 10 feet (3 m) below the anticipated bottom of the rock socket elevation as shown on the plans will be at the rate of 150 percent of the contract price per linear foot (m) of excess. If, for shafts designed in end bearing, the foundation inspection hole is drilled prior to shaft construction or prior to rock socket excavation, coring of the rock above the bottom of the rock socket will be noncompensable.

**701.7.7 Concrete Coring.** Payment for concrete coring will be considered full compensation for all material, labor, tools, equipment, grouting and incidentals necessary to complete the work. The number of feet (m) of cored holes may vary from the estimated quantities, but the contract unit price shall prevail regardless of the variation.

**701.7.8 Sonic Logging Testing.** Payment for sonic logging testing of drilled shafts as required by the engineer will be made at the contract unit price per each for sonic logging testing. No payment will be made for supplementary sonic logging testing to evaluate defects. Payment for sonic logging testing will be considered full compensation for providing all equipment, access pipes, conducting the actual probing measurements as specified, furnishing reports, removing equipment, and all tools, labor and any incidentals necessary to complete the work. The number of sonic logging inspections may vary from the estimated quantities, but the contract unit price shall prevail regardless of the variation.

**701.7.9 Drilled Shaft Load Tests.** Payment will be at the contract unit price and will be considered full compensation for all costs related to the performance of the load tests as specified by the contract documents.

**701.7.10 Welding Inspection.** If evidence of poor welding is found, radiographing or other non-destructive testing of welds required by the engineer will be noncompensable and any effect on time of performance nonexcusable.