SECTION 511 - DRILLED SHAFTS

511.01 Description. This work includes labors, materials, equipment and services necessary to install drilled shafts according to the contract. Drilled shafts include reinforced or unreinforced concrete with or without concrete bell footings.

511.02 Qualifications of Drilled Shaft Contractor. The Contractor shall have installed drilled shafts according to the contract. The Contractor shall conform to Subsection 102.01 - Prequalification of Bidders and below.

Because of the expertise required to successfully complete the drilled shafts, conduct load tests, and do other related work, a qualified Contractor or subcontractor shall install the drill shaft. The Contractor or subcontractor shall have installed a minimum of five (5) drilled shafts, similar to that proposed, for at least three (3) years. The Contractor shall have a supervisory personnel who participated in the construction of drilled shafts similar to the type proposed for a duration of at least three (3) years within the last ten (10) years.

511.03. Materials. Materials shall conform to the following:

(A) Portland Cement Concrete. Concrete shall conform to Section 601 - Structural Concrete except the concrete shall have minimum twenty-eight (28) day compressive strength f'_c = 4500 pounds per square inch.

The Contractor shall proportion the concrete mix designs to get properties of high workability, compaction under self weight and resistance to segregation. The maximum nominal aggregate size shall be three-quarters (3/4) inch. The slump range shall be seven (7) $\pm$ one (1) inch for concrete poured into a water free borehole and eight (8) $\pm$ one (1) inch for concrete placed under water or under drilling slurry. Slump for the concrete shall be a minimum of four (4) inches after four (4) hours from initial mixing. The Engineer will not permit superplasticizers.

(B) Reinforcing Steel. Reinforcing steel shall conform to Section 602 - Reinforcing Steel.

511.04. Construction Requirements.

(A) General.

(1) Drilled Shaft Submittals. At the time of bid, the Contractor shall submit:

(a) a list containing at least three (3) projects completed in the last three (3) years on which the Contractor has installed drilled shafts of a diameter and length similar to those shown in the contract and

(b) a signed statement that the Contractor has inspected both the project site and the subsurface information including soil or rock samples made available in the contract documents.

The list of projects shall contain names and phone numbers of owner's representatives who can verify the Contractor's participation on that project.

At least one (1) month before constructing the drilled shafts, * the Contractor shall submit an installation plan for acceptance by the Engineer. This plan shall provide information on the following:

(a) Name and experience record of the drilled shaft superintendent in charge of drilled shaft operations for this project,

(b) List of proposed equipment such as cranes, drills, augers, bailing buckets, final cleaning equipment, tremies or concrete pumps, and casing,

(c) Details of construction operation sequence and the * sequence of shaft construction in bents or groups,

(d) Details of shaft excavation methods,

(e) When the contract requires slurry, details of the methods * to mix, circulate and desand slurry,

(f) Details of methods to clean the shaft excavation,

(g) Details of reinforcement placement including support and centralization methods,

(h) Details of concrete placement including proposed operational procedures for free fall, tremie, or pumping methods,

(i) Details of required load tests including equipment and procedures, and recent calibrations for jacks or load cells supplied by the Contractor.

(j) Other information shown in the contract or requested by the Engineer.

The Engineer will evaluate the drilled shaft installation plan for conformance with the contract within fourteen (14) days after * receipt of the plan, the Engineer will notify the Contractor of additional information required and/or changes necessary to meet the contract requirements. The Engineer will reject parts of the *

plan that are unacceptable. The Contractor will resubmit changes for re-evaluation. Procedural acceptance given by the Engineer shall be subject to trial in the field. The acceptance shall not relieve the Contractor of the responsibility to complete the work according to the contract.

(2) Trial Shaft Installation. The Contractor shall show the adequacy of its methods and equipment by successfully constructing an unreinforced test shaft. The Contractor shall position this trial shaft away from production shafts in the location shown in the contract or as ordered by the Engineer. The Contractor shall drill the trial shaft to the maximum depth shown in the contract. When shown in the contract, the Contractor shall require the reaming of bells at specified trial shaft holes to establish the feasibility of belling in a specific soil strata.

Failure to show the Engineer the adequacy of methods and equipment shall be reason for the Engineer to require alterations in equipment and/or method by the Contractor. Additional trial holes required to show the adequacy of altered methods of construction or equipment shall be at the at no cost to the State. Once the Engineer has given acceptance to construct production shafts, the Engineer will not permit changes in the methods or equipment used to construct the satisfactory test shaft without consent of the Engineer.

The Contractor shall fill the trial shaft holes with unreinforced concrete similar to the construction of production shafts. The Contractor shall cut the concreted trial shafts off two (2) feet below finished grade and leave in place. The Contractor shall restore the disturbed areas at the sites of the trial shaft holes to their original condition.

(3) Protection of Existing Structures. The Contractor shall prevent damage to existing structures and utilities. Preventive measures shall include:

(a) selecting construction methods and procedures that will prevent caving of the shaft excavation,

(b) monitoring and controlling the vibrations from construction activities such as the driving of casing or sheeting, drilling of the shaft, or from blasting, if the Engineer permits blasting.

(4) Construction Sequence. The Contractor shall complete the excavation to footing elevations before shaft construction begins unless accepted in writing by the Engineer. The Contractor shall repair the disturbances caused by shaft installation to the footing area before the Contractor pours the footing.

When the Contractor installs drilled shafts with embankment placement, the Contractor shall construct drilled shafts after the placement of fills unless accepted in writing by the Engineer. *

The Contractor shall not cap the drilled shafts, constructed before the completion of the fills, until the Contractor have placed the fills as near to final grade as possible. The Contractor shall leave only the necessary work room for construction of the caps. *

(B) **Construction Methods.**

(1) General. The Contractor shall excavate for shafts and bell footings, to the dimensions and elevations shown in the contract. Its methods and equipment shall be suitable for the intended purpose and materials met. The Contractor shall construct the drilled shafts according to the contract. The Contractor shall use the permanent casing method only when required by the contract or authorized by the Engineer. The Engineer will permit blasting only if stated on the contract or authorized in writing by the Engineer. *

(2) Dry Construction Method. The Contractor shall use this method only at sites where the groundwater table and soil conditions are suitable to permit construction of the shaft in a dry excavation. The Engineer may inspect the sides and bottom of the shaft visually before the Contractor places the concrete. The dry method includes drilling the shaft excavation, removing accumulated water and loose material from the excavation, and placing the shaft concrete in a dry excavation. *

(3) Wet Construction Method. The Contractor shall use this method at sites where the Contractor cannot maintain a dry excavation for placement of the shaft concrete. This method includes using water or mineral slurry to maintain stability of the hole perimeter while advancing the excavation to final depth, placing the reinforcing cage, and concreting the shaft. *

If the Contractor locates drilled shafts in open water areas, the Contractor shall extend the exterior casings from above the water elevation into the ground. The Contractor shall install the exterior casing to produce a positive seal at the bottom of the casing so that no intrusion or extrusion of water or other materials occurs into or from the shaft excavation. *

(4) Casing Construction Method. The Contractor may use the casing method when shown in the contract or at sites where the dry or wet construction methods are inadequate. The Contractor may place the casing either in a predrilled hole or advanced through the ground by twisting, driving or vibration before the Contractor cleans the casing. *

(C) **Excavation.**

(1) General. The Contractor shall make the shaft excavations at locations, and to shaft geometry and dimensions shown in the contract. The Contractor shall lower drilled shaft tip elevations when the material met during excavation is unsuitable and/or differs from that anticipated in the design of the drilled shaft.

The Contractor shall maintain a construction method log during shaft excavation. The log shall contain information such as:

(a) excavation diameters,

(b) type of material excavated with the elevations of the material

(c) rate of excavation

(d) the description of and approximate top and bottom elevation of each soil or rock material

(e) seepage or groundwater, and

(f) remarks

On projects with cofferdams, the Contractor shall provide a qualified diver to inspect the cofferdam conditions when the contract requires a seal for construction. Before placing the concrete seal, the diver shall inspect the cofferdam interior periphery. The cofferdam interior periphery inspection includes each sheeting indentation and around each drilled shaft.

The Contractor shall dispose the excavated material according to Section 203 - Excavation and Embankment.

When shown in the contract, the Contractor shall excavate the bells to form the height and a bearing area of the size and shape specified in the contract. The Contractor shall excavate the bell mechanically.

The Contractor shall furnish drilled shaft concrete required to fill excavations for the bells and shafts dimensioned in the contract at no cost to the State.

The Contractor shall not permit workers to enter the shaft excavation unless:

(a) the Contractor installs a suitable casing and the Contractor lowers and stabilizes the water level, below the level the workers will occupy, and

(b) the Contractor provides adequate safety equipment and procedures to workers entering the excavation.

(2) Excavation and Drilling Equipment. The excavation and drilling equipment shall have adequate capacity including power, torque, and down thrust to excavate a hole to the maximum diameter and to a depth of ten (10) feet or twenty (20) percent beyond the depths shown in the contract whichever is greater.

The excavation and overreaming tools shall be of adequate design, size and strength to do the work shown in the contract. When the Contractor cannot drill using conventional earth augers and/or underreaming tools, the Contractor shall provide special drilling equipment including rock core barrels, rock tools, air tools, blasting materials and other equipment as necessary to construct the shaft excavation to the size and depth required. The Engineer will permit blasting only if stated on the contract or authorized in writing by the Engineer.

The Contractor shall require the sidewall overreaming when the sidewall of the hole have softened, swelled, or degraded. Overreaming thickness shall be a minimum of half (1/2) inch and a maximum of three (3) inches. The Contractor may overream with a grooving tool, overreaming bucket or other accepted equipment. The thickness and elevation of sidewall overeaming shall be according to the contract. The Contractor shall overream sidewall and place additional shaft concrete at no cost to the State.

(3) Standard Excavation. Standard excavation is excavation done with conventional tools. Conventional tools include augers fitted with soil or rock teeth, drilling buckets, and overreaming (belling buckets) attached to drilling equipment. This drilling equipment shall be of the size, power, torque, and down thrust (crowd) accepted for use by the Engineer after successful construction of a trial drilled shaft.

(4) Special Excavation. Special excavation is excavation that requires special tools and/or procedures to do hole advancement. The Engineer will pay for special Excavation below the depth where conventional tools and drilling equipment accepted for standard excavation, operating at maximum power, torque and down thrust, cannot advance the hole. The Contractor shall get the refusal rate using the standard excavation tools and equipment when hole advancement is less than one (1) foot after fifteen (15) minutes of continuous drilling at full power.

The Engineer will consider special excavation, except obstructions removal, despite the density or character of materials met.

(5) Unclassified Excavation. When the contract designates drilled shaft excavation as unclassified, the Contractor shall provide the necessary equipment to remove and dispose of materials met in forming the drilled shaft excavation. The Engineer will not make separate payment for excavation of materials of different densities and character or employment of special tools and procedures necessary to excavate. The Engineer will pay for obstruction removal separately.

(6) Classified Excavation. When designated in the contract, the Contractor shall do classified excavation under standard and special excavation items. The Engineer will pay for obstruction removal separately.

(7) Obstructions Removal. The Contractor shall remove obstructions at drilled shafts locations. Such obstructions shall include man-made materials such as old concrete foundations and natural materials such as boulders. The Contractor shall employ special procedures and/or tools after the Contractor cannot advance the hole using conventional augers fitted with soil or rock teeth, drilling buckets and/or underreaming tools. Such special procedures/tools may include: chisels, boulder breakers, core barrels, air tools, hand excavation, temporary casing, and increasing the hole diameter.

The Engineer will not permit blasting unless accepted in writing by the Engineer.

The Engineer will not consider drilling tools that the Contractor loses in the excavation an obstructions. The Contractor shall remove the drilling tools promptly. The cost due to tools lost in the excavation shall be at no cost to the State including costs associated with hole degradation due to removal operations or the time the hole remains open.

(8) Exploration (Shaft Excavation). The Contractor shall take soil samples or rock cores where shown in the contract or as ordered by the Engineer to resolve the character of the material directly below the completed shaft excavation. The Contractor shall extract the soil samples with a split or undisturbed sample tube. The Contractor shall cut the rock cores with an accepted double or triple tube core barrel. The Contractor shall cut to a minimum of ten (10) feet below the bottom of the drilled shaft excavation at the time the shaft excavation is about complete. The Engineer may require the Contractor to extend the depth of the coring up to a total depth of twenty (20) feet. The Contractor shall measure the rock core and standard penetration test samples, identify visually, and describe on its log. The Contractor shall place the samples in suitable containers, identify by shaft location, elevation, and project number. The Contractor shall deliver the samples with its

field log to the Engineer within twenty-four (24) hours after the Contractor completes the exploration. The Engineer will inspect the samples or cores and decide the final depth of required excavation based on the Engineer's evaluation of the materials suitability. The Contractor shall furnish two (2) copies of the typed final Contractor's log to the Engineer at the time the Contractor completes the shaft excavation and accepted.

(D) **Casings.**

(1) **General.** Casings shall be steel, smooth, watertight, and of ample strength to withstand both handling and driving stresses and the pressure of concrete and the surrounding earth materials. The inside diameter of the casing shall not be less than the specified size of the shaft. The Engineer will not allow extra compensation for concrete required to fill the oversized casing or oversized excavation. The Contractor shall remove casings, except permanent casing, from shaft excavations. The length of permanent casings installed below the shaft cutoff elevation, shall remain in place.

When the shaft extends above ground or through a body of water, the Contractor may form them with removable casing except permanent casing. For permanent casings, the Contractor shall remove the portion of metal casings between an elevation two (2) feet below the lowest water elevation and the top of shaft elevation after the Contractor cures the concrete. The Contractor shall remove the casing carefully so that the casing will not damage the concrete. The Contractor may use special casing systems that the Contractor designed to permit removal after the concrete hardens in open water areas, when accepted. The Contractor may remove the casings when the concrete attains sufficient strength provided:

(a) the Contractor continues to cure the concrete for the full seventy-two (72) hours period according to the contract,

(b) the Contractor does not expose the shaft concrete to salt water or moving water for seven (7) days and

(c) the concrete reaches a compressive strength of at least two thousand five hundred (2,500) pounds per square inch.

(2) **Temporary Casing.** The Engineer will consider subsurface casing temporary unless shown in the contract as permanent casing. The Contractor shall remove the temporary casing before the Contractor completes placing concrete in the drilled shaft. The Contractor may require telescoping, predrilling with slurry, and/or overreaming to beyond the outside diameter of the casing to install casing.

If the Contractor chooses to remove a casing and substitute a longer or larger diameter casing through caving soils, the Contractor shall stabilize the excavation. The Contractor shall stabilize the excavation with slurry or backfill before the Contractor installs the new casing. The Contractor may use other accepted methods to control the stability of the excavation and protect the integrity of the foundation soils.

Before the Contractor withdraws the casing, the level of fresh concrete in the casing shall be the higher of the following:

(a) a minimum of five (5) feet above the hydrostatic water level or

(b) the level of drilling fluid.

As the Contractor withdraws the casing, the Contractor shall maintain an adequate level of concrete within the casing so that the Contractor:

(a) displaces the fluid trapped behind the casing upward and

(b) discharges the fluid at the ground surface without contaminating or displacing the shaft concrete.

If temporary casings become bound or fouled during shaft construction and the Contractor cannot remove the temporary casings, the Engineer will consider the drill shaft defective. The Contractor shall improve such defective shafts according to the contract. Such improvement may consist of removing the shaft concrete and extending the shaft deeper providing the Contractor straddles the shaft or replaces the shaft. The Contractor shall do corrective measures including redesign of footings caused by defective shafts according to the contract at no cost to the State or extension of the contract time. The Engineer will not pay for the casing remaining in place.

(3) Permanent Casing. The Contractor shall use permanent casing when specified in the contract. The casing shall be continuous between top and bottom elevations according to the contract. After the Contractor completes installation, the Contractor shall cut off the permanent casing at the prescribed elevation. The Contractor shall complete the shaft by installing necessary reinforcing steel and concrete in the casing.

If special temporary casings are in the contract or ordered in writing by the Engineer, the Contractor shall maintain the alignment of the temporary out casing with the permanent inner casing and a positive, watertight seal between the two (2) casings during excavation and concreting operations.

(E) Slurry. The Contractor shall use only mineral slurries when the Contractor uses slurry in the drilling process. The slurry shall have a mineral grain size that will remain in suspension and sufficient viscosity and gel characteristics to transport excavated material to suitable screening system. The percentage and specific gravity shall be sufficient to maintain the stability of the excavation and to allow proper concrete placement. During construction, the Contractor shall maintain the level of the slurry at a height sufficient to prevent caving of the hole. If a sudden significant loss of slurry occurs, the Contractor shall delay the construction of that foundation until the Contractor submits an alternate construction procedure for acceptance.

The Contractor shall premix the mineral slurry thoroughly with clean fresh water and adequate time (as prescribed by the mineral manufacturer) allotted for dehydration before introduction into the shaft excavation. The Contractor shall require the slurry tanks of adequate capacity for slurry circulation, storage, and treatment. The Engineer will not allow excavated slurry pits in lieu of slurry tanks without the written permission of the Engineer. The Contractor shall provide desanding equipment as necessary to control slurry sand content to less than four (4) percent by volume in the borehole. The Engineer will not require desanding equipment for setting temporary casing, sign post, or lighting mast foundations. The Contractor shall prevent the slurry from "setting up" in the shaft, such as: agitation, circulation and/or adjusting the properties of the slurry. The Contractor shall dispose of slurry and in suitable areas off from the project site.

The Contractor shall carry out the control tests using suitable apparatus on the mineral slurry to resolve the density, viscosity and pH. An acceptable range of values for those physical properties is in Table 511-1.

The Contractor shall test the density, viscosity and pH value during the shafts excavation to establish a consistent working pattern. The Contractor shall make a minimum of four (4) sets of tests during the first eight (8) hours of slurry use. When the results show consistent behavior, the Contractor shall decrease the testing frequency to one (1) set every four hours of slurry use.

TABLE 511-1 - SODIUM BENTONITE OR ATTAPULGITE IN FRESH WATER			
Property	Range of Values*		Test Method
	Time of Slurry Introduction	In Hole at Time of Concreting	
Density(pcf)	64.3** - 69.1**	64.3Y** - 75.0**	Density Balance
Viscosity (sec/qt)	28 - 45	28 - 45	Marsh Cone
pH	8 - 11	8 - 11	pH paper pH meter
* At twenty (20) degrees Celsius			
** Increase by two (2) pounds per cubic foot in salt water			

Notes: a. The Engineer may modify the values if the Contractor does not need to control the bottom hole conditions or if tests shows that other criteria are appropriate.

b. If the contract requires desanding, the sand content shall not exceed four (4) percent (by volume) in the bore hole as resolved by the American Petroleum Institute sand content test.

c. The Contractor shall submit changes for acceptance in writing by the Engineer.

The Contractor shall ensure that the bottom of the shaft does not accumulate heavily contaminated slurry suspension. The heavily contaminated slurry suspension could impair the free flow of concrete. Before the Contractor places concrete in the shaft excavation, the Contractor shall take slurry samples from the base of the shaft using a sampling tool. The Contractor shall extract slurry samples from the base of the shaft and at intervals not exceeding ten (10) feet up the shaft. The Contractor shall extract samples until two (2) consecutive samples produce acceptable values for density, viscosity, pH, and sand content.

When the Contractor finds unacceptable slurry samples, the Contractor shall take actions necessary to bring the mineral slurry as specified in the contract. The Contractor shall not pour the concrete until resampling and testing results produce acceptable values.

The Contractor shall furnish the reports of tests required above to the Engineer on completion of each drilled shaft. An authorized person of the Contractor shall sign the reports.

During construction, the Contractor shall maintain at the level of mineral slurry not less than four (4) feet above the highest piezometric water pressure along the depth of a shaft. If the slurry construction method fails according to the contract, the Contractor shall then stop this method and propose an alternate method for acceptance.

(F) Excavation Inspection. The Contractor shall provide equipment for checking the dimensions and alignment of each permanent shaft excavation. The Contractor shall decide the dimensions and alignment according to the contract. The Contractor shall measure the final shaft depths with a suitable weighted tape or other accepted methods after final cleaning. A minimum of fifty (50) percent of the base of each shaft will have less than half (1/2) inch of sediment at the time of placement of the concrete. The maximum depth of sediment or debris on the base of the shaft shall not exceed one and a half (1-1/2) inches. The Engineer will decide the shaft cleanliness by visual inspection for dry shafts or other methods deemed appropriate to the Engineer for wet shafts. Also, for dry excavations the maximum depth of water shall not exceed three (3) inches before concrete pour.

(G) Reinforcing Steel Cage Construction and Placement. The Contractor shall assemble and place the reinforcing steel cage immediately after the Engineer inspects and accepts the shaft excavation before concrete placement. The reinforcing steel cage includes longitudinal bars, ties, cage stiffener bars, spacers, centralizers, and other necessary appurtenances to complete the cage.

If the bottom of the constructed shaft elevation is lower than shown in the contract, the Contractor shall extend at least half (1/2) of the longitudinal bars required in the upper portion of the shaft the additional length. The Contractor shall continue the tie bars for the extra depth, spaced two (2) foot on center. The Contractor shall extend the stiffener bars to the final depth. These bars may be lap splice or unspliced bars of the proper length. The Engineer will not permit welding to the reinforcing steel.

The Contractor shall tie and support the reinforcing steel in the shaft so that the reinforcing steel will remain within allowable tolerances given in Subsection 511.04(I). The Contractor shall use the concrete spacers or other accepted noncorrosive spacing devices at sufficient intervals (near the bottom and at intervals not exceeding ten (10) feet up the shaft) to insure concentric spacing for the entire cage length. The Contractor shall construct the spacers of accepted material equal in quality and durability to the concrete specified for the shaft. The spacers shall be of adequate dimension to insure a minimum of three (3) inch annular space between the outer portion of the reinforcing cage and the side of the excavated hole. The Contractor shall provide accepted cylindrical concrete feet (bottom supports) to maintain the proper distance between bottom of the cage and base of the shaft excavation.

The Contractor shall check the elevation of the top of the steel cage before and after the Contractor places concrete. If the Contractor does not maintain the rebar within the specified tolerances, the Contractor shall make the corrections according to the contract. The Contractor shall not construct additional shafts until the Contractor has modified the rebar cage support according to the contract.

(H) Concrete Placement.

(1) General. The Contractor shall place the concrete according to Subsection 511.03 and herein.

The Contractor shall place the concrete, if possible, immediately after reinforcing steel placement.

Concrete placement shall be continuous from the bottom to the top elevation of the shaft. Concrete placement shall continue after the shaft is full until good quality concrete is evident at the top of shaft. The Contractor shall place the concrete through a tremie, concrete pump or by drop chute using accepted methods as described below.

The elapsed time from the beginning of concrete placement in the shaft to the completion of the placement shall not exceed two (2) hours. The Contractor shall adjust the accepted admixtures on the job site so that concrete remains in a workable plastic state throughout the two (2) hour placement limit. Before the Contractor places the concrete, the Contractor shall provide test results of a trial mix and a slump loss test. An accepted testing laboratory shall conduct the test using accepted methods. The Contractor may request a longer placement time. The Contractor shall supply a concrete mix that will maintain a slump of four (4) inches or greater. The Contractor shall conduct the trial mix and slump loss tests using concrete and ambient temperatures appropriate for site conditions.

(2) Concreting by Tremie. The Contractor may use tremies for concrete placement in wet or dry holes. Tremie used to place concrete shall include a tube of sufficient length, weight, and diameter to discharge concrete at the shaft base elevation. The tremie shall not contain aluminum parts that will have contact with the concrete. The tremie inside diameter shall be at least six (6) times the maximum size of aggregate used in the concrete mix but shall not be less than ten (10) inches. The inside and outside surfaces of the tremie shall be clean and smooth to permit flow of concrete and unimpeded withdrawal during concreting. The wall thickness of the tremie shall be adequate to prevent crimping or sharp bends that restrict concrete placement.

The tremie used for wet excavation concrete placement shall be watertight. Underwater placement shall not begin until the Contractor places the tremie to the shaft base elevation. The Contractor may use valves, bottom plates or plugs only if concrete discharge begins within one (1) tremie diameter of the base.

The Contractor shall remove the plugs from the excavation or an accepted material that will not cause a defect in the shaft if not removed.

The Contractor shall construct the discharge end of the tremie to permit the free radial flow of concrete during placement operations. The Contractor shall immerse the tremie discharge end at least five (5) feet in concrete after starting the flow of concrete. The flow of concrete shall be continuous. The Contractor shall maintain the concrete in the tremie at a positive pressure differential to prevent water or slurry intrusion into the shaft concrete.

If during the concrete pour, the Contractor removes the tremie line orifice from the fluid concrete column and discharges concrete above the rising concrete level, the Engineer will consider the shaft defective. In such case, the Contractor shall remove the reinforcing cage and concrete, the necessary sidewall removal ordered by the Engineer and repour the shaft. Costs of replacement of defective shafts shall be at no costs to the State.

(3) Concreting by Pump. The Engineer may use concrete pumps and lines for concrete placement in wet or dry excavations. Pumps and pump lines used to place concrete shall be of sufficient length, weight, and diameter to discharge concrete at the shaft base elevation. The pump and pump lines shall not contain aluminum parts that will have contact with the concrete. Pump lines shall have a minimum four (4) inches diameter. The Contractor shall construct the pump lines with watertight joints. Concrete placement shall not begin until the pump line discharge orifice is at the shaft base elevation.

For wet excavations, the Contractor shall use a plug or similar device to separate the concrete from the fluid in the hole until pumping begins. The Contractor shall remove the plug from the excavation or be of a material accepted by the Engineer that will not cause a defect in the shaft if not removed.

The discharge orifice shall remain at least five (5) feet below the surface of the fluid concrete. When lifting the pump line during concreting, the Contractor shall temporarily reduce the line pressure until the Contractor has repositioned the orifice at a higher level in the excavation.

If during the concrete pour, the Contractor removes the pumpline orifice from the fluid concrete column and discharges concrete above the rising concrete level, the Engineer will consider the shaft defective. In such case, the Contractor shall remove the reinforcing cage and concrete, complete necessary sidewall removal ordered by the Engineer, and repour the shaft. Costs of replacing the defective shaft shall be at no cost to the State.

(4) Concreting by Drop Chutes. The Engineer will permit free fall placement of concrete only in dry holes. Dry excavations are excavations where the maximum depth of water does not exceed three (3) inches. The Contractor shall use the drop chutes to direct placement of free fall concrete.

The Engineer will not permit free fall method in wet excavations. Drop chutes shall include a smooth tube of one (1) piece construction or sections that the Contractor may add or remove. The Contractor may place the concrete through a hopper at the top of the tube or side openings during concrete placement. The Contractor shall support the drop chute so that the free fall of the concrete measured from the bottom of the chute is less than twenty-five (25) feet. Concrete placed by free fall shall fall directly to the base without contacting the rebar cage or hole sidewall. If concrete placement causes the shaft excavation to cave or slough, or if the concrete strikes the rebar cage or sidewall, the Contractor shall reduce the height of free fall or reduce the rate of concrete flow into the excavation. If the Contractor cannot place the concrete satisfactorily by free fall according to the contract, the Contractor shall use tremie or concrete pump to pour.

(I) Construction Tolerances. The following construction tolerances apply to drilled shafts:

(1) The drilled shaft shall be within one twelfth (1/12) of the shaft diameter or three (3) inches, whichever is less, in the horizontal plane at the plan elevation for the top of the shaft.

(2) The vertical alignment of the shaft excavation shall not vary from the plan alignment by more than quarter (1/4) inch per foot of depth. The alignment of a battered shaft excavation shall not vary by more than half (1/2) inch per foot of depth from the prescribed batter.

(3) After the Contractor places the concrete, the top of the reinforcing steel cage shall be no more than six (6) inches above and no more than three (3) inches below plan position.

(4) Casing diameters shown in the contract refer to outside diameter (OD) dimensions. When accepted, the Contractor may choose to provide a casing larger in diameter than shown in the contract to ease meeting this requirement. When the Contractor is not using casing, the minimum diameter of the drilled shaft shall be one (1) inch less than the specified shaft diameter. When the Contractor uses a series of telescoping casings, the Contractor shall size the casing so that the Contractor can maintain the minimum shaft diameters listed above.

(5) The Contractor shall excavate the bearing area of bells to the plan bearing area as a minimum. The diameter of the bells shall not exceed three (3) times the specified shaft diameter. The Contractor may vary other plan dimensions shown for the bells, when accepted.

(6) The top elevation of the shaft shall have a tolerance of ± one (1) inch from the plan top of shaft elevation.

(7) The dimensions of casing are subject to American Pipe Institute tolerances applicable to regular steel pipe.

(8) The Contractor shall design the excavation equipment and methods so that the completed shaft excavation will have a flat bottom. The cutting edges of excavation equipment shall be normal to the vertical axis of the equipment within a tolerance of ± three-eighths (3/8) inch per foot of diameter.

Drilled shaft excavations that the Contractor cannot complete within the required tolerances are unacceptable. When accepted, the Contractor may make corrections to an unacceptable drilled shaft excavation by accepted combination of the following methods:

~~(1)~~ Overdrill the shaft excavation to a larger diameter to permit accurate placement of the reinforcing steel cage with the required minimum concrete cover.

(2) Increase the number or size of the reinforcing steel.

(3) Enlarge the bearing area of the bell excavation within the tolerances allowed.

The acceptance of correction procedures is dependent on analysis of the effect of the degree of misalignment and improper positioning. The Engineer may accept the correction methods as design analysis. A Licensed Professional Engineer shall sign the redesign drawings and computations. The Contractor shall correct out of tolerance drilled shaft excavations including engineering analysis and redesign at no cost to the State.

(J) Drilled Shaft Load Tests. When the contract documents include static load testing, the Contractor shall complete the load tests before construction of production drilled shafts. The Contractor shall allow seven (7) working days after the Contractor completes the last load test before the Engineer provides estimated drilled shaft tip elevations for production shafts.

The Contractor shall obtain the services of a Licensed Professional Engineer with satisfactory load test experience:

(1) to conduct the test according to the contract,

(2) record data and

(3) furnish reports of the test results to the Engineer.

The use of load tests, the number of load tests and locations shall be shown in the contract or as ordered by the Engineer. The Contractor shall load the load test shaft to a maximum test load equal to three (3) times the design service load, or to plunging failure, whichever occurs first. Plunging failure is a deflection of the shaft head equal to five (5) percent of the shaft diameter.

Static load testing shall not begin until the concrete has attained a compressive strength of three thousand four hundred (3400) pounds per square inch. The Contractor shall load test the drilled shafts in the order ordered by the Engineer. The Contractor shall complete the static load tests as described in ASTM D 1143 (Compression Test) quick test method and ASTM D 3966 (Lateral Test) or as modified herein. The Contractor shall supply equipment necessary to conduct the static test. The Contractor shall design the loading frame apparatus to ease the maximum load plus an adequate safety factor.

The Contractor shall notify the Engineer within ten (10) calendar days of contract award of the load testing schedule.

The Engineer will require load cells for drilled shaft load tests. Load cells shall be of adequate size to measure the maximum load to the applied shaft. The Contractor shall equip the load cell with an adequate readout device. Before load testing begins, the Contractor shall furnish a certificate from an accepted testing laboratory. The certificate shall show the calibration for the load cell within the preceding six (6) months for stages of loading and unloading. The accuracy of the load cell shall be within one (1) percent of the true load.

After the Contractor completes the test, the Contractor shall cut off the test shafts and reaction shafts at an elevation two (2) feet below the finished ground surface. The portion of the shafts cut off and removed shall remain the property of the Contractor.

511.05 Method of Measurement.

(A) Furnishing Drilled Shaft Drilling Equipment. The Engineer will not measure the equipment for furnishing drilled shaft equipment when contracted on a lump sum basis.

(B) Drilled Shafts. The Engineer will measure drilled shafts per linear foot complete in place.

The length shall be the difference between the plan top of shaft elevation and the final bottom of shaft elevation.

(C) Standard Excavation. The Engineer will measure standard excavation per linear foot.

The Engineer will measure the standard excavation along the centerline of the shaft including bells.

(D) Special Excavation. The Engineer will measure special excavation per linear foot.

The Engineer will measure the standard excavation along the centerline of the shaft including bells.

(E) Unclassified Shaft Excavation. The Engineer will measure unclassified shaft excavation per linear foot.

The Engineer will measure the standard excavation along the centerline of the shaft including bells. The Engineer will measure the length from the difference between the plan top of shaft elevation to the plan estimated tip elevation.

(F) Unclassified Extra Depth Excavation. The Engineer will measure unclassified extra shaft excavation per linear foot.

The Engineer will measure from the shaft estimated tip elevation shown in the contract to the final authorized and accepted bottom of shaft elevation.

(G) Obstructions. The Engineer will measure obstructions by the hour per obstruction.

The Engineer will measure the obstruction after the Engineer authorizes the removal of the obstruction and resume excavation. The Engineer will include the disposal of the removed obstruction material in the time spent to remove obstruction.

The Engineer will not include the length of obstruction removed under this item in the quantities of other excavation items. The Engineer will subtract them from the total depth of the applicable excavation item. *|

(H) Drilled Shaft Sidewall Overreaming. The Engineer will measure drilled shaft sidewall overreaming per linear foot. *|

The Engineer will measure the drilled shaft sidewall overreaming between the elevation limits shown in the contract or authorized by the Engineer. *| |

(I) Trial Shaft Holes. The Engineer will measure the trial shaft holes per linear foot. *|

The Engineer will measure the difference between the existing ground surface elevation at the center of the test shaft hole before drilling and authorized bottom elevation of the hole including bells. *|

(J) Exploration (Shaft Excavation). The Engineer will measure the exploration per linear foot. *|

The Engineer will measure from the bottom of shaft elevation to the bottom of the exploration hole for each authorized exploration drilled below the shaft excavation. *|

(K) Load Tests. The Engineer will measure the load test per each. *|

(L) Permanent Casings. The Engineer will measure the permanent casings per linear foot. *|

The Engineer will measure along the casing from the top of the shaft elevation or the top of casing, whichever is lower, to the bottom of the casing at each shaft location where the Contractor uses permanent casing. *|

(M) Instrumentation and Data Collection. The Engineer will not measure instrumentation and data collection when contracted on a lump sum basis. *|

(N) Protection of Existing Structures. The Engineer will not measure protection of existing structures when contracted on a lump sum basis. *|

511.06 Basis of Payment |

(A) Furnishing Drilled Shaft Drilling Equipment. The Engineer will pay for furnishing drilled shaft drilling equipment at the contract lump sum price. *|

The price shall be full compensation for furnishing and moving the drilling equipment to the project, setting the equipment up at the locations and removing the equipment from the project and furnishing labors, materials, tools, and incidentals necessary to complete the work. *|

The Engineer will pay for sixty (60) percent of the amount bid for this item when the drilling equipment is on the job site, assembled, and ready to drill foundation shafts. *|

The Engineer will pay for the remaining forty (40) percent of the amount bid when the Contractor has drilled the shafts, and the Contractor has placed the shaft concrete up to the top of the shafts. *|

(B) Drilled Shafts. The Engineer will pay for the accepted quantities of drilled shafts at the contract unit price per linear foot for drilled shaft of the diameter specified. *|

The price shall be full compensation for furnishing and installing concrete and reinforcing steel, furnishing labors, materials, equipment, tools, and incidentals necessary to complete the drilled shaft. *|

(C) Standard Excavation. The Engineer will pay for the accepted quantities of standard excavation at the contract unit price per linear foot for drilled shafts of the diameter specified. *|

The price shall be full compensation for furnishing labors, materials, equipment, tools, and incidentals necessary to complete the drilled shaft. *|

(D) Special Excavation. The Engineer will pay for the accepted quantities of special excavation at the contract unit price per linear foot for drilled shafts of the diameter specified. *|

The price shall be full compensation for furnishing labors, materials, equipment, tools, and incidentals necessary to complete the drilled shaft. *|

(E) Unclassified Shaft Excavation. The Engineer will pay for the accepted quantities of unclassified shaft excavation at the contract unit price per linear foot for drilled shafts of the diameter specified. *|

The price shall be full compensation for furnishing and installing the temporary casing, removing and disposing of excavated materials, using slurry as necessary, using drilling equipment, blasting, using special tools and drilling equipment to excavate the shaft to the depth shown in the contract, and furnishing labors, materials, equipment, tools and incidentals necessary to complete the work. *|

(F) Unclassified Extra Depth Excavation. The Engineer will pay for the accepted quantities of unclassified extra depth excavation at one hundred and fifty (150) percent of the contract unit price per linear foot of the diameter specified. *|

The price shall be full compensation for the costs of excavating below the bottom of shaft elevations shown in the contract except the additional costs included under the associated pay items for permanent casing. Work under this item is the same as that described under unclassified shaft excavation and additional work of excavating below the plan bottom of shaft elevation. *|

The Engineer will pay for compensation under this item only when the Engineer authorizes the extra depth excavation. *|

(G) Obstructions. The Engineer will pay for the accepted quantities of removing the obstructions at the contract unit price per hour of obstructions removed. *|

The maximum payment per designated obstruction shall not exceed twenty (20) times the unit cost for standard excavation or unclassified excavation whichever is less.

The price shall be full compensation for furnishing labors, materials, tools, equipment, and incidentals necessary to complete the work. |

(H) Drilled Shaft Sidewall Overreaming. The Engineer will pay for the accepted quantities of drilled shaft sidewall overreaming at the contract unit price per linear foot. |

The price shall be full compensation for furnishing labors, materials, tools, equipment, and incidentals necessary to complete the work. |

(I) Trial Shaft Holes. The Engineer will pay for the accepted quantities of trial shaft holes of the specified diameter at the contract unit price per linear foot. *|

The price shall be full compensation for excavating the trial shaft holes through to the bottom of shaft elevation shown in the contract or as authorized by the Engineer (using mineral slurry as necessary), providing inspection facilities, backfilling the hole, restoring the site as required, furnishing labors, materials, tools, equipment, and incidentals necessary to complete the work. *|

The Engineer will not pay for trial shaft holes that the Contractor failed to show to the Engineer the adequacy of its proposed methods and equipment. *|

(J) Exploration (Shaft Excavation). The Engineer will pay for the accepted quantities of exploration at the contract unit price per linear foot. *|

The price shall be full compensation for taking soil samples, rock cores of the diameter and length required and authorized by the Engineer, drilling, extraction, packaging and classifying the samples or cores, delivering them to the Engineer, furnishing concrete to fill the core hole, furnishing labors, materials, tools, equipment, and incidentals necessary to complete the work. *|

(K) Load tests. The Engineer will pay for the accepted quantities of load tests at the contract unit price per each complete in place. *|

The price shall be full compensation for load tests, costs related to the performance of the load test, furnishing labors, materials, tools, equipment, and incidentals necessary to complete the work. *|

(L) Permanent Casings. The Engineer will pay for the accepted quantities of permanent casings at the contract unit price per linear foot complete in place. *|

The price shall be full compensation for furnishing, and placing the permanent casing in the shaft excavation, furnishing labors, materials, tools, equipment, and incidentals necessary to complete the work. *|

(M) Instrumentation and Data Collection. The Engineer will pay for furnishing instrumentation and data collection at the contract lump sum price. *|

The price shall be full compensation for furnishing labors, materials, tools, and incidentals necessary for instrumentation and data collection and load test report when required. *|

(N) Protection of Existing Structures. The Engineer will pay protection of existing structures at the contract lump sum price. *|

The price shall be full compensation for furnishing labors, materials, tools, and incidentals necessary to complete the work. *|

The Engineer will make payment under: *|

Pay Item	Pay Unit
Furnishing Drilled Shaft Drilling Equipment	Lump Sum
Drilled Shaft	Linear Foot
Standard Excavation	Linear Foot
Special Excavation	Linear Foot
Unclassified Shaft Excavation	Linear Foot
Unclassified Extra Depth Excavation	Linear Foot
Drilled Shaft Sidewall Overreaming	Linear Foot
Obstructions	Per Hour
Trial Shaft Holes	Linear Foot
Exploration (Shaft Excavation)	Linear Foot
Load Test	Each
Permanent Casing	Linear Foot
Instrumentation and Data Collection	Lump Sum
Protection of Existing Structures	Lump Sum