ITEM 524 DRILLED SHAFTS

524.01 Description. This work consists of furnishing and installing drilled shafts. The lengths of the drilled shafts shown on the plans are estimated from available subsurface information. Furnish the proposed drilled shafts according to plan requirements, with the understanding that the actual length required is based on conditions encountered during construction and may differ from the estimated length shown on the plans.

524.02 Materials. Furnish material conforming to:

Concrete, Class S 511
Epoxy coated reinforcing steel 509

524.03 Contractor's Installation Plan. Submit, for the Engineer's acceptance, a written installation plan of procedures to follow when excavating the hole, placing the concrete, and monitoring the concrete placement. Submit the installation plan at least 14 Calendar Days before constructing the drilled shafts. Include the following information:

A. Details of the sequence proposed for the overall drilled shaft construction operation.

B. Procedures for maintaining correct horizontal and vertical alignment of the excavation.

C. If using a casing, method to advance the casing.

D. If using a temporary casing, details of the methods to extract the temporary casing and to maintain the concrete slump to keep concrete workable by adding admixtures such as retarders or superplasticizers.

E. If using slurry, details of the methods to mix, circulate, and de-sand the slurry. For polymer slurry, submit the manufacturer's recommendations for use of the 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. A list of proposed equipment to be used such as cranes, drills, augers, bailing buckets, final cleaning equipment, de-sanding equipment, slurry pumps, tremies, concrete pumps, casings, etc.

Acceptance of the installation plan will not relieve the Contractor of the responsibility for obtaining the required results.

524.04 Hole Excavation. Take precautions to prevent damaging existing structures and utilities. Precautions include, but are not limited to, selecting construction methods and procedures that will prevent excessive caving of the shaft excavation, and monitoring and controlling the vibrations from the driving of casing or sheeting or drilling of the shaft.

When encountered, remove objects such as large boulders. Do not blast unless shown on the plans or authorized in writing by the Engineer.

Unless otherwise shown on the plans, where drilled shafts are to be installed in conjunction with embankment placement, construct shafts after the placement of the fill and completion of any specified settlement periods.

Excavate for the shafts to the dimensions and elevations shown on the plans. Use methods and equipment suitable for the intended purpose and materials encountered. Use either the dry method, wet method, temporary casing method, or permanent casing method as necessary to produce sound, durable concrete foundation shafts free of defects. When a particular method of construction is required on the plans, that method shall be used. If no particular method is specified for use, select and use a method based on site conditions.

If the excavation operation is stopped, protect the shaft cavity by installing a safety cover. The Contractor is responsible for the safety of the shaft excavation, surrounding soil, and the stability of the sidewalls. If necessary to ensure such safety and stability, use a temporary casing, slurry, or other methods accepted by the Engineer. Unless cased to the full depth, do not leave excavations unfilled overnight.

Use appropriate means, such as a cleanout bucket or air lift, to clean the bottom of the excavation of all shafts. Promptly notify the Engineer when unexpected obstructions are encountered.

A. Dry Construction Method. Use the dry construction method only at sites where the groundwater table and site conditions are suitable to allow 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 may be visually inspected before placing the concrete. The dry method consists of excavating the drilled shaft hole, removing accumulated water, and loose material from the excavation, and placing the shaft concrete in a relatively dry excavation. The rate of flow of water into the hole should not be more than 12 inches (300 mm) within a 1-hour period. Do not place the initial concrete if there is more than 3 inches (75 mm) of water in the bottom of the hole.

B. Wet Construction Method. Use the wet construction method at sites where a dry excavation cannot be maintained for placement of the shaft concrete. The wet method consists of using water or slurry to contain seepage and groundwater movement and

placing concrete using a tremie or concrete pump. Additionally, use this method to maintain stability of the hole perimeter while advancing the excavation to its final depth, placing the reinforcing cage, and placing the shaft concrete. This method also consists of de-sanding and cleaning the slurry. For drilled shafts that are not socketed into the bedrock and during drilling operations, maintain a water or slurry fluid elevation inside the shaft excavation higher than the static water table. Unless demonstrated to the Engineer's satisfaction that the surface casing is not required, provide temporary surface casings to aid shaft alignment and position and to prevent sloughing of the top of the shaft excavation. Extend surface casings from the ground surface to a point in the shaft excavation where sloughing of the surrounding soil does not occur.

C. Temporary Casing Construction Method. Use the temporary casing construction method when the stability of the excavated hole and/or the effects of groundwater must be controlled. Remove temporary casings while the concrete remains workable. As the casing is being withdrawn, maintain a 5-foot (1.5 m) minimum head of fresh concrete in the casing so that all the fluid trapped behind the casing is displaced upward without contaminating the shaft concrete. As necessary, increase the required minimum concrete head to counteract groundwater head inside the casing. Extract casing at a slow, uniform rate with the pull in line with the shaft axis. Rotate, tap, push down, or vibrate the casing when necessary to extract it. Rotate the casing as little as possible to avoid deforming the reinforcing steel cage.

D. Permanent Casing Construction Method. The permanent casing construction method generally consists of driving or drilling a casing to a specified depth before excavation begins. If full penetration of the casing to the specified depth cannot be attained, the Contractor may either excavate material within the embedded portion of the casing or excavate a pilot hole ahead of the casing until the casing reaches the desired penetration. Make the pilot hole no larger than one-half the diameter of the shaft and center the hole in the shaft. Do not over ream to the outside diameter of the casing unless specifically shown on the plans.

Ensure that the casing is continuous between the elevations shown on the plans. Unless otherwise shown on the plans, do not use temporary casing instead of or in addition to the permanent casing.

After installing the casing and excavating the shaft, place the reinforcing steel, then place the shaft concrete. After filling the permanent casing with concrete, pressure grout voids between the shaft excavation and the casing with cement grout. Submit the method of pressure grouting the voids to the Engineer for approval. Pressure grouting is required to ensure contact (bearing) between the casing and any surrounding soil layer that is used for lateral support.

524.05 Friction Type Drilled Shafts. Friction type drilled shafts are defined as drilled shafts that do not bear on bedrock and obtain their ability to support load from a combination of end bearing on the soil and adhesion between soil and concrete along the length of the shaft.

For friction type drilled shafts, dry construction method may be used for cohesive soils only. If using a casing for the construction of a friction type drilled shaft, remove the casing completely or partially as shown on the plans. If enough water is entering the hole through the sides and bottom of the hole such that the supporting soils are being

eroded, maintain a positive head of fluid in the excavation hole to ensure that water is not continuously flowing into the hole.

If the Engineer determines that the hole sidewall has softened due to excavation methods, swelled due to delays in concreting, or degraded because of slurry cake buildup, over ream the sidewall to sound material. If the concrete is not placed the same day that the excavation is completed, protect the excavation with a temporary casing, and redrill the hole at least 6 inches (150 mm) larger in diameter, clean the excavation, and perform slurry test before concreting.

524.06 Casings. Use smooth, watertight, steel casings of sufficient strength to withstand handling and driving stresses and the concrete and surrounding earth pressures. Provide an outside diameter of the steel casing equal to or greater than the plan diameter of the shaft. If the plan diameter of the bedrock socket is same as the drilled shaft above the bedrock and a steel casing is used, provide a diameter of the bedrock socket as shown on the plans. Ensure that the diameter of the casing is large enough to allow the excavation of the bedrock socket.

Where drilled shafts are located in open water areas, extend the casing a minimum of 12 inches (300 mm) above the water to protect the shaft concrete from water action during placement and curing of the concrete. Cut off the casing at the plan top of drilled shaft elevation after the concrete has cured. If practical, install the casing in a manner that produces a positive seal at the bottom of the casing to prevent piping of water or entry of other material into the shaft excavation.

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

524.07 Slurry. Slurry used in the drilling process shall be a mineral or polymer slurry. The mineral slurry 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. Ensure that the percentage and specific gravity of the material used to make the suspension is sufficient to maintain the stability of the excavation and to allow proper concrete placement. Maintain the level of the slurry at a height sufficient to prevent caving of the hole.

Thoroughly premix the mineral slurry with clean fresh water and allow adequate time for hydration before introduction into the shaft excavation. Agitate, circulate, and adjust the properties of the slurry to prevent the slurry from “setting up” in the shaft excavation.

Perform control tests using suitable apparatus on the mineral slurry to determine density, viscosity, and pH. Conform to the acceptable range of values for these physical properties as shown in Table 524.07-1.

TABLE 524.07-1 MINERAL SLURRY SPECIFICATIONS RANGE OF VALUES AT 68 °F (20 °C)

Property	Test Method	Time of Slurry Introduction	Time of Concreting in Hole
Density lb/ft^3 (kg/m^3)	Density Balance	64.3 to 69.1 (1030 to 1107)	64.3 to 75.0 (1030 to 1201)
Viscosity s/qt (s/L)	Marsh Cone	28 to 45 (30 to 48)	28 to 45 (30 to 48)
pH	pH Paper or meter	8 to 11	8 to 11

If de-sanding is required, do not allow the sand content to exceed 4 percent by volume at any point in the shaft excavation as determined by the American Petroleum Institute sand content test.

Determine density, viscosity, and pH values before and during the shaft excavation to establish a consistent working pattern.

Before placing shaft concrete, use an approved slurry-sampling tool to take slurry samples from the bottom and at mid-height of the shaft. Eliminate heavily contaminated slurry that has accumulated at the bottom of the shaft. Ensure that the mineral slurry conforms to the requirements specified immediately before shaft concrete placement.

Only use polymer slurry after demonstrating to the Engineer that the stability of the hole perimeter can be maintained while advancing the excavation to its final depth by excavating a trial hole of the same diameter and depth as that of the production shafts. Use the same polymer slurry in the trial hole as proposed for the production shafts. If using different sizes of the shafts at the project, use the same size trial hole as that of the largest diameter shaft, except the depth of the trial hole need not be more than 40 feet (12 meters). Only one trial hole per project is required. Do not use the trial hole excavation for a production shaft. After completing the trial hole excavation, fill the hole with sand. The acceptance of the polymer slurry does not relieve the Contractor of responsibility to maintain the stability of the excavation. Polymer slurry shall conform to the manufacturer's requirements.

524.08 Excavation Inspection. Provide equipment for checking the dimensions and alignment of each shaft excavation. Determine the dimensions and alignment. Measure the final shaft depth after final inspection.

Immediately before placing concrete, ensure that the bottom of the completed drilled shaft excavation is as clean as practical. Remove drilling spoils that adhere to the vertical sides of the bedrock socket.

524.09 Reinforcing Steel for Drilled Shafts. Place the reinforcing steel cage as a unit immediately after inspection of the excavation and before placing concrete. If not placing the concrete immediately after installing the cage, the Contractor may have to remove the cage before placing the concrete to verify the integrity of the excavated area and to ensure loose material is removed from the bottom of the hole.

Tie and support the reinforcing steel so it remains within the required tolerances. Securely tie spacers at quarter points around the cage perimeter and space at intervals not to exceed 5 feet (1.5 m) along the length of the cage. If the size of the longitudinal reinforcing steel equals or exceeds 1-inch (25 mm) in diameter, the Contractor may

increase the minimum spacing of the spacing devices to 10 feet (3 m). Use spacers of adequate dimensions to ensure a minimum annular space between outside of cage and side of hole or casing of 3 inches (75 mm) for shaft diameters up to 4 feet (1.2 m) and 6 inches (150 mm) for shaft diameters larger than 4 feet (1.2 m). The Contractor may use round plastic spacers.

Maintain the top of the reinforcing steel cage no more than 6 inches (150 mm) above and no more than 3 inches (75 mm) below the required position. If the reinforcing steel cage is not maintained within tolerances, make acceptable corrections and do not construct additional shafts until the method of reinforcing steel cage support has been approved.

When approved by the Engineer, the Contractor need not provide the reinforcing steel for the extended length of the drilled shaft if it is determined in the field that the Contractor must drill the shaft deeper than the estimated length.

524.10 Concrete for Drilled Shafts. For all drilled shafts, use Class S concrete according to Item 511 except as modified and supplemented as follows. The required slump is 6 ± 1 inch (150 ± 25 mm). Achieve the additional slump over 4 inches (100 mm) by using chemical admixtures conforming to 705.12, Type F or G. The maximum water-cement ratio shall not exceed 0.44. If placing concrete under water, add 10 percent more cement to the concrete mix. If placing concrete using a tremie, further increase the slump to 8 ± 1 inch (200 ± 25 mm), by using chemical admixtures.

For wet method construction, place concrete in one continuous operation from bottom to top of the shaft. After the concrete has reached the top of the drilled shaft, continue pumping and remove all contaminated concrete until acceptable quality concrete is evident at the top of the shaft. Do not vibrate concrete with a vibrator. Carefully remove the casing so that the reinforcing steel cage is not deformed by the force of the downward flowing concrete.

Do not place concrete in any drilled shaft excavation without acceptance from the Engineer. Inspect the drilled shaft excavation immediately before placing the concrete. Provide a light powerful enough to thoroughly inspect the reinforcing steel cage, the sides, and the bottom of the drilled shaft. The inspection for the wet construction method consists of only probing and measuring.

If the elevation of the top of the shaft is below ground at the time of concrete placement, use a casing to prevent caving of materials into fresh concrete.

524.11 Free Fall Concrete Placement. The Contractor may place the concrete in a dry drilled shaft excavation using the free fall method provided the concrete falls to its final position through air without striking the sides of the hole, the reinforcing steel cage, or any other obstruction. Use a centering drop chute, at least 3 feet (1 m) long with the free fall method. Unless shown on the plans, there is no limit to the height of free fall. If the concrete placement causes the shaft excavation to cave or slough or if the concrete strikes the rebar cage or sidewall, reduce the height of free fall or the rate of concrete flow into the excavation, or both.

If the Engineer determines that dewatering is not practical or placement by free fall method cannot be accomplished, place the concrete using a tremie or a concrete pump.

524.12 Tremie. The Contractor may use a gravity tremie to place concrete placement instead of a concrete pump in either wet or dry holes. For uncased wet holes, maintain the drilled shaft excavation full of slurry or water to such a depth that water does not flow into the shaft excavation at any time. To place concrete, use tremies consisting of a tube of sufficient length, weight, and diameter to discharge concrete at the shaft base elevation. If the tremie contains aluminum parts, do not allow these parts to contact the concrete. Use tremies with an inside diameter of at least 10 inches (250 mm). Ensure that the inside and outside surfaces of the tremie are clean and smooth to allow both flow of concrete and unimpeded withdrawal during concreting. Use tremies with a wall thickness adequate to prevent crimping or sharp bends that restrict concrete placement.

For concrete placement, use water-tight tremies. Do not begin underwater placement until the tremie is placed to the shaft bottom elevation. Use valves, bottom plates, or plugs so concrete discharge can begin within one tremie diameter of the base. Either remove plugs from the excavation or use plugs of an Engineer approved material that does not cause a defect in the shaft if not removed. Construct the discharge end of the tremie to allow the free radial flow of concrete during placement operations. Immerse the tremie discharge end at least 10 feet (3 m) in concrete at all times after starting the flow of concrete.

If the tremie line orifice is removed from the fluid concrete column during the concrete pour, and discharges concrete above the rising concrete level, consider the drilled shaft defective.

524.13 Pumped Concrete. Pump concrete into either wet or dry holes. For uncased wet holes, maintain the drilled shaft excavation full of slurry or water to such a depth that water does not flow into the shaft excavation at any time. Use concrete pump pipe at least 4 inches (100 mm) in diameter and constructed with watertight joints. Arrange the concrete pump equipment so no vibrations result that might damage fresh concrete. Arrange pipes carrying concrete from the pump to the shaft with a minimum number of bends. Anchor the pipe used to convey the concrete to the bottom of the drilled shaft excavation to the steel casing or another suitable stationary object to prevent the pipe from undulating during the initial placement of the concrete. Do not begin placing concrete until the pump line orifice is at the shaft base elevation.

Do not use aluminum pipe as a conveyance for the concrete. Pump an adequate quantity of grout, mortar, or concrete without coarse aggregate through the equipment ahead of the specification concrete to provide lubrication to the pumping system. Do not place the concrete used for lubrication in the shaft. The lubrication process will not be repeated as long as the pumping operations are continuous. Operate the pump so a continuous stream of concrete without air pockets is produced. To prevent the contamination of the concrete placed initially at the bottom of the shaft, seal the outlet end of the pumping pipe with a diaphragm or plug that is flushed out when the hydrostatic pressure from the column of concrete exceeds that of the water in the shaft. Control the initial rate of concrete placement so not to lift or displace the cage of reinforcing steel. Use a watertight conveying system, and leave the outlet end well below the top of the freshly placed concrete. The preferred concrete placement procedure is to maintain the outlet end of the pumping system at approximately 10 feet

(3 m) below the top of the fresh concrete. When the concrete reaches the top of the drilled shaft column, remove all laitance.

If the concrete pump line orifice is removed from the fluid concrete column during the concrete pour, and discharges concrete above the rising concrete level, the drilled shaft shall be considered defective.

524.14 Construction Tolerances. For shafts supporting single columns, position the drilled shaft within 3 inches (75 mm) of the plan location in the horizontal plane at the plan elevation for the top of the shaft. For shafts supporting footings, position the center within 6 inches (150 mm) of the plan location. Do not allow the vertical alignment of the shaft to vary from the required alignment by more than 1/4 inch per foot (21 mm/m) of depth. Construct the supported elements at the plan location. Perform all corrections required to construct the supported elements.

524.15 Inspection Records. Provide all necessary equipment and labor needed to obtain measurements for completing the Inspection Records. Obtain measurements before placing concrete.

524.16 Method of Measurement. The City will measure Drilled Shafts by the number of feet (meters), measured along the axis of the drilled shaft from the required bottom elevation of the shaft to the proposed top plan elevation. The City will not measure the length of reinforcing steel projecting from the drilled shaft into the pier column or the footing supported on Drilled Shafts as shown on the plans. If the drilled shaft extends into the bedrock, The City will divide the total length of each drilled shaft into two segments. The length of the lower segment is the length of the bedrock socket, and the length of the upper segment is the length of the drilled shaft above the bedrock socket.

If a steel casing extending down to bedrock is used, the City will measure the bedrock socket from the bottom of the casing to the bottom of the drilled bedrock excavation. If the Engineer is assured that a portion of the metal casing is embedded in solid bedrock, and upon the Engineer's concurrence, the City may include the embedded distance as a part of the bedrock socket.

524.17 Basis of Payment. Payment is full compensation for performing required excavation; furnishing and placing steel casings; furnishing and placing reinforcing steel and concrete by free fall, pumping, or tremie method; removing casings; casings left in place; supplying equipment and performing slurry testing; supplying and disposing of slurry; and disposing excess excavated material.

The City will not pay for the cost of performing slurry tests before concreting.

The City will not make separate payment for the trial holes.

The City will not pay for corrections required to construct the supported elements.

The City will pay for accepted quantities at the contract prices as follows:

Item	Unit	Description
524	Foot (Meter)	Drilled Shafts, ___" (___ mm) Diameter, above Bedrock
524	Foot (Meter)	Drilled Shafts, ___" (___ mm) Diameter, into Bedrock

524.17

524	Foot (Meter)	Drilled Shafts, ___" (___ mm) Diameter