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**Section 718. DRILLED SHAFTS**

**718.01. Description.** This work consists of providing and constructing drilled shaft foundations.

**718.02. Materials.** Provide materials in accordance with the following:

Concrete, Grade S2, T .....	<u>701</u>
Steel Reinforcement .....	<u>905</u>
Casing.....	<u>906</u>

Provide steel reinforcement meeting the yield strength shown on the plans.

Provide Concrete, Grade S2 in dry conditions and Concrete, Grade T in under-water conditions for Drilled Shafts. Modify slump for site conditions as follows:

- A. From 6 inches to 8 inches for conditions except concrete placement under water or under drilling slurry,
- B. From 7 inches to 9 inches for concrete placed under water or under drilling slurry.

**718.03. Construction.** Review available soil boring logs from subsurface investigations. If, during construction, actual subsurface conditions differ substantially from those reported on the boring logs, notify the Engineer in writing within 48 hours of determining the discrepancy.

The complete geotechnical report, outlining the subsurface exploration conducted during the design phase, is available for review before bidding. The Department does not intend for boring log data as representation or warranties of continuity. The Department is not responsible for interpretations or conclusions drawn by the Contractor.

The Contractor may perform additional soil test borings and other exploratory procedures at no additional cost to the Department.

**A. Drilled Shaft Installation Plan.** Submit an installation plan, for the Engineer's approval, 21 calendar days before beginning drilled shaft installation. Provide detailed information on the following:

- 1. Proposed equipment, including cranes, drills, augers, core barrels, bailing buckets, final cleaning equipment, slurry pumps, tremies or concrete pumps, and casing;
- 2. The construction sequence;
- 3. Shaft excavation methods, including proposed excavation methods through supporting and caving soil layers;

4. Methods to mix, circulate, and de-sand slurry;
5. Methods to clean shaft excavation;
6. Reinforcement placement, including support and centering methods;
7. Concrete placement, including free fall, tremie, or concrete pumping procedures;
8. Drilled shaft installation plan, including methods to prevent drilled shaft excavation spoils from entering waterways, wetlands and floodplains;
9. A fall protection plan conforming to the MIOSHA Construction Safety Standards, including a rescue plan for shafts with a diameter of at least 30 inches and at least 6 feet deep, in place before drilling; and
10. Other information shown on the plans or requested by the Engineer.

The Engineer will evaluate the drilled shaft installation plan and notify the Contractor, within 7 calendar days of receiving the plan, of additional information required and changes to meet contract requirements.

The Engineer will reject unacceptable parts of the plan. Resubmit changes for reevaluation. Drilled shaft installation plan procedures are subject to trials in the field.

The Engineer's approval does not relieve the Contractor of completing the work and is not cause for extra compensation if construction methods or equipment do not provide a satisfactorily drilled shaft.

**B. General Methods and Equipment.** Excavate for the drilled shaft, to the dimensions and elevations shown on the plans, through encountered materials. Use methods and equipment for the intended purpose and materials encountered. Control operations to prevent damage to existing structures and utilities. Use preventative measures including the selection of construction methods and procedures that prevent caving of the shaft excavation, and monitoring and controlling the excavation depth. Repair damage to existing structures or utilities, to the satisfaction of the Engineer, including engineering analysis and redesign, without extending the project completion dates, and at no additional cost to the Department. Obtain the Engineer's approval for the selected general method.

1. **Dry Construction Method.** Use the dry construction method at sites where the groundwater table and site conditions allow shaft construction in dry excavation, and where the sides and bottom of the shaft remain stable without caving, sloughing, squeezing or swelling. Ensure the Engineer can visually inspect the shaft before concrete placement.

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Excavate the drilled shaft hole, remove accumulated water and loose material, and place the shaft concrete in a dry excavation. Ensure the flow rate of water into the excavation does not exceed 12 inches within 1 hour. Do not place the initial concrete if the depth of water in the bottom of the excavation exceeds 3 inches.

2. **Wet Construction Method.** Use the wet construction method at sites where dry excavation cannot be maintained during shaft concrete placement. Use water or slurry to contain seepage and groundwater movement and place concrete using a tremie or concrete pump. Maintain the stability of the excavation perimeter while advancing the excavation to the final depth, placing the reinforcing cage, and placing the shaft concrete. De-sand and clean slurry, if used.

Maintain a water or slurry fluid elevation higher than the static water table during drilling operations and inside drilled shafts not connected into the bedrock.

Unless otherwise approved by the Engineer, provide temporary surface casings for shaft alignment and position and to prevent sloughing of the top of the shaft excavation. Extend surface casings to an elevation in the shaft excavation that prevents sloughing of the surrounding soil.

3. **Dry Temporary Casing Method.** Use the dry temporary casing method where caving soils occur but casing can maintain a dry and stable excavation. In dry soil, install a temporary casing through the caving soils to the bottom of shaft. If ground water is present, install a temporary casing to an impermeable stratum. Remove excess water and soil from the casing.

Advance the casing and excavation simultaneously. Do not drill outside or below the casing through caving soil layers. Ensure the bottom of the excavation remains dry and stable until placement of the reinforcing steel and concrete. Withdraw the casing while the concrete is workable. Before withdrawing casing, increase the level of fresh concrete in the casing to ensure the upward displacement of fluid behind the casing.

4. **Wet Temporary Casing Method.** Use the wet temporary casing method where caving soils occur and a dry excavation cannot be maintained, the soil profile is permeable, and the groundwater elevation is higher than the bottom of the shaft elevation. Install the casing through caving soils to the required bottom of shaft elevation, and drill the excavation to the required dimensions. Advance the

casing and excavation simultaneously. Do not drill outside or below the casing through caving soil layers.

Maintain a positive pressure differential between the fluid level in the excavation and the groundwater elevation during drilling, excavation, and clean out. Place reinforcing steel and pump or tremie concrete to the bottom of the excavation. Displace water inside the casing with concrete. Do not pump water out of the casing.

The wet temporary casing method may include drilling slurry. Perform final cleaning of the excavation with a clean out bucket. Before and during casing removal, increase the level of fresh concrete in the casing to ensure the upward displacement of fluid behind the casing, without contaminating or displacing the shaft concrete.

5. **Construction Method Log.** Submit to the Engineer a Daily Construction Method Log during drilled shaft excavation and construction. Ensure the log includes the following information for each drilled shaft:
  - a. Date (start date and completion date);
  - b. Drilled shaft identification number;
  - c. Location;
  - d. Actual top and bottom elevation of drilled shaft;
  - e. Shaft diameter;
  - f. Final centerline location at top;
  - g. Variation of drilled shaft from plumb;
  - h. Top and bottom elevation of any permanent casing;
  - i. Description of each soil and rock material encountered during excavating and the top and bottom depths or elevations;
  - j. Depth drilled into bearing stratum;
  - k. Top and bottom elevations of obstructions encountered;
  - l. Amount of obstruction time;
  - m. Depth or elevation of encountered seepage or groundwater;
  - n. Record the actual volume of concrete placed with the theoretically calculated concrete volume to detect any large voids or intrusions of extraneous material; and
  - o. Remarks.
- C. **Construction Tolerances.**
  1. **Horizontal Alignment.** Drill shafts within 3 inches of the centerlines shown on the plans at the top-of-shaft elevation.
  2. **Plumb.** Ensure the bottom elevation of the drilled shaft is out-of-plumb by no more than 1 percent of the drilled shaft length, as

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measured horizontally from the actual center of the shaft at the shaft design top elevation.

3. **Reinforcing Steel.** Maintain the top of the reinforcing steel cage no greater than 1 inch above and no greater than 3 inches below the required position. If the reinforcing steel cage is not within the tolerances specified, correct the position.

Do not construct additional shafts until the Engineer approves the method of reinforcing steel cage support.

4. **Top of Shaft Elevation.** Ensure the top elevation of the shaft is from +1 inch to -3 inches from the top of shaft elevation shown on the plans.

The Engineer will consider drilled shaft excavations and completed shafts, not constructed within the required tolerances, unacceptable. Correct unacceptable shaft excavations and completed shafts to the Engineer's satisfaction. Complete corrections for out-of-tolerance drilled shafts, including engineering analysis, and redesign, at no additional cost to the Department, and with no extension to the project completion dates.

- D. **Casings.** Case shaft excavations, as shown on the plans. Cut off temporary, left-in-place casing at the elevation shown on the plans.

Provide smooth, watertight, metal casings capable of withstanding handling, installation, and the pressure of concrete and the surrounding earth materials. Provide a casing with an inside diameter at least the size of the shaft. Remove casings from the excavation, except those approved by the Engineer for the permanent casing.

Attach fixtures to the top of the casings, to aid in removing temporary casings. Remove temporary casings while the concrete remains workable. Complete concrete placement in the shaft before removing temporary casing. Extract casings slowly, with the pull in-line with the shaft axis. Do not apply forces that induce moments in the shaft, detrimental to the concrete.

- E. **Slurry.** If using slurry in the drilling process, use polymer type slurry. Provide polymer slurry with viscosity and gel characteristics capable of transporting excavated material to a screening system or settling tank. Ensure the percentage and specific gravity of the material making the suspension maintains the stability of the excavation and allows concrete placement. Maintain the height of the slurry capable of preventing the excavation sides from caving and the excavation bottom from heaving.

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

Perform control tests using an apparatus on the slurry to determine density, viscosity, and pH in accordance with ASTM or AASHTO standards. Ensure density, viscosity, and pH values meet the ranges specified in Table 718-1.

<b>Table 718-1 Polymer Slurry Specifications Range of Values at 68 °F</b>			
<b>Property</b>	<b>Test Method</b>	<b>At Time of Slurry Introduction (Emulsified Polymer)</b>	<b>At Time of Concreting in Excavation (Emulsified Polymer)</b>
Density, lb/ft <sup>3</sup>	Density Balance	<63	<63
Viscosity, s/qt	Marsh Cone	33 – 43	33 – 43
pH	pH Paper or meter	8 – 11	8 – 11
Maximum Contact Time (hr)	—	72	72
Sand Content	API-13B-1	<1%	<1%

If de-sanding is required, do not allow the sand content to exceed 1 percent by volume 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 a Department-approved slurry-sampling tool to take slurry samples from the bottom, and at mid-height, of the shaft. Eliminate heavily contaminated slurry accumulated at the bottom of the shaft.

Control slurry exiting the excavation. Contain slurry in the excavation and remove as it becomes displaced by concrete placement.

**F. Excavation.** Maintain the stability of the excavation sidewalls and extend the shaft excavation to a stratum accepted by the Engineer. Extend drilled shaft tip elevations if the Engineer determines the bearing stratum, encountered during excavation, is unsuitable or differs from the bearing stratum anticipated in the design of the drilled shaft.

Provide the Engineer access to auger cuttings of the bearing material for additional analysis. Fill shaft over-excavation with concrete at no additional cost to the Department, unless Engineer determines the

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bearing stratum encountered during excavation is unsuitable or differs from the bearing stratum anticipated in the design of the drilled shaft. Fill unauthorized shaft excavations extended below required depths or elevations with concrete, at no additional cost to the Department.

Dispose of excavated material, removed from shaft excavations, in accordance with section 205. Keep excavated materials away from open shaft excavations. Direct surface water away from shaft excavations. Ensure excavated material does not enter waterways, wetlands or floodplains.

1. **Inspection.** Provide equipment for checking the dimensions and alignment of each permanent drilled shaft. Use the following methods to determine the dimensions and alignment with the Engineer's direction:
  - a. Check drilled shaft dimensions and alignment with reference stakes and plumb bob;
  - b. Check the dimensions and alignment of casing inserted in the excavation;
  - c. Insert a casing in shaft excavations temporarily; or
  - d. Insert a rigid rod assembly with several 90-degree offsets equal to the shaft diameter, into the shaft excavation.

After shaft excavation, provide access, lighting, and time for the Engineer to inspect the shaft if a tremie pour is not required.

Reference the depth of the shaft during drilling to marks on the Kelly Bar. Measure final drilled shaft depths with a weighted tape after final cleaning.

Clean each shaft so at least 50 percent of the base contains less than ½ inch of sediment. Do not leave more than 1½ inch of debris on the base. The Engineer will visually inspect dry excavations and inspect wet excavation by other methods to determine cleanliness.

2. **Obstructions.** Remove surface and subsurface obstructions in the length of excavation at drilled shaft locations. Obstructions may include old concrete foundations, abandoned utilities, or boulders. Use special procedures, tools, or both if unable to advance excavation using augers fitted with soil or rock teeth, drilling buckets, or under-reaming tools. Special procedures and tools include:
  - a. Chisels,
  - b. Boulder breakers,
  - c. Core barrels,
  - d. Air tools,

- e. Hand excavation,
- f. Temporary casing, and
- g. Enlarging the hole diameter.

**G. Placing Steel Reinforcement.** Place steel reinforcement in accordance with subsection 706.03.E.

Assemble the reinforcing steel cage, and place immediately after excavation inspection and immediately before concrete placement. If concrete is not placed immediately after the cage installation, the Engineer may direct removal of the cage before placing the concrete to verify the integrity of the excavated area and ensure removal of loose or soft material from the bottom of the excavation.

Construct the cage of longitudinal bars and lateral reinforcement consisting of spiral reinforcement, lateral ties, or horizontal bands. If overhead obstacles prevent placing the cage as a single unit, connect individual segments with couplers or by lapping steel, as approved by the Engineer. Provide a fully assembled steel reinforcement cage for inspection two working days before to the start of construction.

Tie and support the reinforcing steel to meet the required tolerances. Tie spacers at quarter points around the cage perimeter and space at intervals no greater than 5 feet along the length of the cage. If the size of the longitudinal reinforcing steel equals or exceeds a diameter of 1 inch, the Contractor may increase the minimum distance between spacing devices to 10 feet.

Use spacers to ensure a minimum annular space of 3 inches between the outside of the cage and the side of the excavation or casing. Use at least one spacer per 30 inches of the outside circumference of the cage. Place at least three spacers at each level of the cage.

Use non-corrosive spacers. The Contractor may use round plastic spacers. Do not use concrete blocks, wood blocks, or metal chairs on the sides of the shaft. The Contractor may use concrete blocks on the bottom of the shaft to maintain cover.

Support or hold down the cage to control vertical displacement during concrete placement or casing extraction. Use support, concentric with the cage to prevent the steel from racking and distorting. Check the elevation of the top of the steel cage before and after concrete placement or after casing extraction.

**H. Concrete Placement.** Do not place concrete in drilled shaft excavation before the Engineer accepts the drilled shaft excavation. Inspect the drilled shaft excavation immediately before placing the



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concrete. Provide lighting capable of illuminating the reinforcing steel cage, and the sides and the bottom of the drilled shaft excavation for inspection.

For wet method construction, inspect by probing and measuring. If the top-of-shaft elevation is below ground during concrete placement, use a casing to prevent material from caving into fresh concrete.

Place concrete as soon as possible after completing excavation and placing reinforcing steel.

For dry method construction, remove loose material and accumulated water from the bottom of the excavation before placing concrete. If unable to remove water, place concrete using underwater placement methods.

For wet method construction, place concrete in one continuous operation from bottom to top of the shaft. After the concrete reaches the top of the drilled shaft, continue pumping and remove contaminated concrete until the Engineer determines acceptable quality concrete appears at the top of the shaft. Continue placing concrete through the tremie pipe until contaminated concrete flows over the top of the shaft.

Do not vibrate concrete with a vibrator. When removing the casing, ensure the force of downward flowing concrete does not deform the reinforcing steel cage.

Place concrete by free fall method, tremie, or pumping. Use a sump, or other Department-approved method to channel displaced fluid and concrete away from the shaft excavation. Recover and dispose of slurry as approved by the Engineer. Do not discharge displaced fluids into waterways, wetlands or floodplains. For concrete pours over water, provide a collar or other means to capture slurry and the top portion of the concrete slushed from the shaft.

1. **Free Fall Concrete Placement.** The Contractor may place concrete in a dry drilled shaft excavation using the free-fall method if concrete falls to the final position without striking the sides of the excavation, the reinforcing steel cage, or other obstructions. Use a centering drop chute, at least 3 feet long with the free-fall method.

If concrete placement causes the shaft excavation to cave or slough, or if concrete strikes the rebar cage or sidewall, reduce the height of free-fall, the rate of concrete flow into the excavation, or both. Do not use a shovel or other means to deflect the concrete discharged directly from the truck. Limit the free-fall distance to 80 feet.

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

2. **Tremie.** The Contractor may use a gravity tremie for concrete placement instead of a concrete pump in wet or dry excavations.

Use tremies with a tube of a length, weight, and diameter to discharge concrete at the shaft base elevation. Do not allow aluminum parts to contact the concrete. Use tremies with an inside diameter of at least 10 inches.

Provide tremies with smooth, clean inside and outside surfaces to allow flow of concrete and unimpeded tremie withdrawal during concreting. Use tremies with thick walls to prevent crimping or sharp bends that restrict concrete placement.

For concrete placement, use watertight tremies. Do not begin underwater concrete placement until positioning the tremie to the shaft bottom elevation. Use valves, bottom plates, or plugs to begin concrete discharge within one tremie diameter of the base. Remove plugs from the excavation or use plugs of an Engineer-approved material that does not cause defects 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 in concrete after beginning the concrete flow.

Place concrete continuously until shaft completion. Keep the shaft full of concrete and the tremie submerged in placed concrete. Raise the tremie as necessary to maintain the free flow of concrete and casing stability.

If withdrawal of the submerged end of the tremie interrupts concrete placement, remove the tube, reseal it at the bottom, reinsert the tube into the placed concrete by at least 10 feet, and recharge before continuing the concrete placement.

For uncased wet excavations, maintain the drilled shaft excavation full of slurry or water so water does not flow into the shaft excavation.

For cased shafts, maintain a head of concrete above the bottom of the casing to overcome hydrostatic pressure. Extract casing at a slow, uniform rate with the pull in line with the shaft axis. Monitor the concrete level in the casing during extraction. Stop the extraction and add concrete to the casing to ensure a completely full excavation upon casing removal.

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Ensure the elapsed time from mixing the first concrete placed in the cased shaft to completion of casing extraction, does not exceed the time concrete maintains a slump of over 4 inches. If the elapsed time is exceeded, modify the concrete mix, the construction procedures, or both for subsequent shafts.

- 3. Pumped Concrete.** Pump concrete into wet or dry excavations, using concrete pump pipe with a diameter of at least 4 inches and constructed with watertight joints. Arrange the concrete pump equipment so vibrations do not damage fresh concrete. Arrange pipes carrying concrete from the pump to the shaft with minimal bends. Anchor pipes conveying concrete to the bottom of the drilled shaft excavation to the steel casing or other stationary objects to prevent the pipe from undulating during initial concrete placement. Do not begin concrete placement until positioning the pump line orifice at the shaft base elevation.

Do not use aluminum pipe to convey concrete. Operate the pump to produce a continuous stream of concrete without air pockets. To prevent contamination of concrete placed initially at the bottom of the shaft excavation, seal the outlet end of the pumping pipe with a diaphragm or plug flushed out when the hydrostatic pressure from the column of concrete exceeds that of the water in the shaft excavation.

Control the initial rate of concrete placement to prevent lift or displacement of the reinforcing steel cage. Use a watertight conveying system, and maintain the outlet end at least 10 feet below the top of freshly placed concrete. When concrete reaches the top of the drilled shaft column, remove laitance.

If withdrawal of the submerged end of the pump interrupts concrete placement, remove the tube, reseal it at the bottom, reinsert into the placed concrete by at least 10 feet, and recharge before continuing the concrete placement.

For uncased wet excavations, maintain the drilled shaft excavation full of slurry or water so water does not flow into the shaft excavation.

For cased excavations, maintain a head of concrete above the bottom of the casing to overcome hydrostatic pressure. Extract casing at a slow, uniform rate with the pull in line with the shaft axis. Monitor the concrete level in the casing during extraction. Stop extraction and add concrete to the casing as necessary to ensure a completely full excavation upon casing removal.

Ensure the elapsed time from mixing the first concrete placed in the cased shaft excavation to completion of casing extraction does not exceed the time concrete maintains a slump of over 5 inches. If the elapsed time is exceeded, modify the concrete mix, the construction procedures, or both for subsequent shafts.

**718.04. Measurement and Payment.**

<b>Pay Item</b>	<b>Pay Unit</b>
Drilled Shaft, ___ inch .....	Foot
Drilled Shaft Equipment, Furnished (Structure No.).....	Lump Sum
Temp Casing-Left in Place .....	Foot
Temp Casing .....	Foot
Permanent Casing.....	Foot
Obstruction Removal.....	Dollars

A. **Drilled Shafts.** The unit price for **Drilled Shaft, \_\_\_ inch** includes the cost of the following:

1. Drilled shaft excavation;
2. Temporary casings;
3. Slurry;
4. Shaft concrete;
5. Steel reinforcement cage;
6. Disposal of excavated material and slurry for construction; and
7. Preventative measures for maintaining surface water or drains free of cuttings or slurry.

B. **Casings.**

1. **Temporary Casing-Left in Place.** The unit price for **Temporary Casing-Left in Place** includes the cost of placing temporary casings left in place, as shown on the plans and cutting the casings to the elevation shown on the plans.
2. **Temporary Casing.** The unit price for **Temporary Casing** includes the cost of placing temporary casings as shown on the plans and removing the casings.
3. **Permanent Casing.** The unit price for **Permanent Casing** includes the cost of placing permanent casings as shown on the plans.

C. **Drilled Shafts.** The unit price for **Drilled Shaft Equipment, Furnished**, includes the cost of providing and removing equipment for constructing the drilled shaft and providing and removing equipment for soil and rock excavation.

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D. **Obstruction Removal.** The Department will pay for removing obstructions as **Obstruction Removal** if the Contractor uses the special procedures and tools specified in subsection 718.03.F.2.

The Engineer will designate obstructions for the Contractor's removal. The Department will establish a budget amount to pay for removing obstructions. If the Contractor and Engineer do not agree on a unit or lump sum price, the Engineer may order the work performed on a force account basis in accordance with subsection 109.05.D.