SECTION 16416

DRILLED SHAFT FOUNDATIONS

PART 1 DESCRIPTION

A. Construct foundations consisting of reinforced or non-reinforced concrete drilled shafts with or without bell footings.

PART 2 MATERIALS

A. Use materials that meet the requirements of the following Items:

1. Item 16421, "Hydraulic Cement Concrete"

2. Item 03210, "Reinforcing Steel"

3. Item 16448, "Structural Field Welding"

B. Unless otherwise shown on the plans, use concrete for drilled shafts that meets the requirements of Table 1.

Table 1
Concrete for Drilled Shafts

Drilled Shaft Type	**Concrete**
Non-reinforced	Class A
Reinforced	Class C
Slurry and underwater concrete placement	Class SS

C. Use coarse aggregate Grade 4, 5, or 6 for drilled shaft concrete in reinforced drilled shafts. Grade 2 or 3 may be used if the shaft is dry and reinforcing steel has a 5 in. minimum clear spacing.

D. Use a water-reducing, retarding admixture in all concrete when using casing that will be pulled or when placing shafts underwater or under slurry.

E. Use concrete with slump that meets the requirements of Table 2.

Table 2
Slump Requirements

Placement Type	**Minimum Acceptable Placement Slump, in.**	**Recommended Design and Placement Slump, in.**	**Maximum Acceptable Placement Slump, in.**
Dry	5-1/2	6-1/2	7-1/2
Underwater and under slurry	7	8	9

F. When casing is to be pulled or when concrete is to be placed underwater or under slurry, perform a slump loss test before beginning work. Provide concrete that will maintain a slump of at least 4 in. throughout the entire anticipated time of concrete placement. Time of concrete placement is described in Sections 16416, Part 3, 3.06 "Concrete" and 16416, Part 3, 3.07 "Additional Requirements for Slurry Displacement or Underwater Concrete Placement Methods." Note the temperature of the concrete mix at the beginning of the slump loss test. If concrete temperature at the time of placement into the drilled shaft is more than 10° higher than the slump loss test temperature, do not place the concrete. Use ice or other concrete cooling ingredients to lower concrete temperature, or run additional slump loss tests at the higher temperatures. Slump loss testing will be waived if anticipated time of concrete placement is less than 90 minutes.

G. Use drilling slurry that meets the requirements of Table 3.

Table 3
Slurry Requirements

Before Introduction into the Excavation		**Sampled from the Bottom of the Excavation before Concreting**		
Specific Gravity	**Sand Content**	**Specific Gravity**	**Viscosity (seconds)**	**Sand Content**
≤ 1.10	≤ 1%	≤ 1.15	≤ 45	≤ 6%

H. Use mineral slurry consisting of processed bentonite or attapulgite clays mixed with clean fresh water. Do not use PHPA (partially hydrolized polyacrylamide) polymeric slurry or any other fluid composed primarily of a polymer solution.

I. Before placing concrete, sample slurry from the bottom of the hole, and test it. Use a pump or air lift to remove slurry that does not meet the requirements of Table 3 while adding fresh clean slurry to the top of the hole to maintain the slurry level. Continue this operation until the slurry sampled from the bottom of the hole meets the requirements.

PART 3 CONSTRUCTION

A. Place the shaft to within the following tolerances.

1. Vertical plumbness – 1 in. per 10 ft. of depth.

2. Center of shaft located under column – 1 in. of horizontal plan position.

3. Center of shaft located under footing – 3 in. of horizontal plan position.

B. Complete the embankment at bridge ends before installing drilled shafts that pass through the fill.

3.01 EXCAVATION

A. The plans indicate the expected depths and elevations for encountering satisfactory bearing material. Excavate as required for the shafts and bell footings through all materials encountered to the dimensions and elevations shown on the plans or required by the site conditions. Removal of man-made obstructions not shown on the plans will be paid for in accordance with Item 01025, "Measurement and Payment." If satisfactory founding material is not encountered at plan elevation, adjust the bottom of the shaft or alter the foundation, as determined by the Owner's Representative, to satisfactorily comply with design requirements. Blasting is not allowed for excavations.

B. If caving conditions are encountered, stop drilling and adopt a construction method that stabilizes the shaft walls.

C. Do not excavate a shaft within 2 shaft diameters (clear) of an open shaft excavation, or one in which concrete has been placed in the preceding 24 hours.

D. Dispose of material excavated from shafts and bells and not incorporated into the finished project. Dispose of excavated material in accordance with the plans and with federal, state, and local laws.

E. Provide suitable access, lighting, and equipment for proper inspection of the completed excavation and for checking the dimensions and alignment of shafts and bell excavation.

3.02 CORE HOLES

A. If directed, take cores to determine the character of the supporting materials. Use a method that will result in recovery of an intact sample adequate for judging the character of the founding material. Such cores should be at least 5 ft. deeper than the proposed founding grade or a depth equal to the diameter of the shaft, whichever is greater. Take these cores when the excavation is approximately complete.

3.03 CASING

A. Use casing when necessary to prevent caving of the material or to exclude ground water. Provide casing with an outside diameter not less than the specified diameter of the shaft. Use casing strong enough to withstand handling stresses and pressures of concrete and of the surrounding earth or water, and that is watertight, smooth, clean, and free of accumulations of hardened concrete.

B. Drill the portion of the shaft below the casing as close as possible to the specified shaft diameter. The portion of shaft below the casing may be as much as 2 in. smaller than the specified shaft diameter.

C. Use construction methods that result in a minimal amount of disturbed soil being trapped outside the casing. This does not apply to temporary undersized casings used to protect workers inside shafts or to drilled shafts designed for point bearing only.

D. Do not leave any casing in place unless authorized or shown on the plans. Do not extract casing until after placing the concrete to an appropriate level. Maintain sufficient concrete in the casing at all times to counteract soil and water pressure. Before and during concrete placement, rotate or move the casing up or down a few inches if necessary to facilitate extraction of the casing.

3.04 REQUIREMENTS FOR SLURRY DISPLACEMENT METHOD

A. Unless otherwise shown on the plans, the slurry displacement method may be used to construct drilled shafts. Use this method to support the sides of the excavation with processed mineral slurry that is then displaced by concrete to form a continuous concrete shaft.

B. Do not use casing other than surface casing. Do not use surface casing longer than 20 ft. without approval. Do not extract the surface casing until after placing the concrete.

C. For slurry mixed at the project site, pre-mix it in a reservoir of sufficient capacity to fill the excavation and for recovery of the slurry during concrete placement. Do not mix slurry in the shaft excavation or other hole. Allow adequate time for hydration of the slurry prior to introduction into the excavation.

D. During and after drilling maintain a head of slurry in the shaft excavation at or near ground level or higher as necessary to counteract ground water pressure.

E. Just before placing reinforcing steel, use an air lift or proper size cleanout bucket to remove any material that may have fallen from the sides of the excavation or accumulated on the bottom after the completion of drilling. Use a cleanout bucket if material is too large to be picked up with an air lift.

F. If concrete placement is not started within 4 hours of the completion of the shaft excavation, reprocess the hole with the auger as directed. Then clean the bottom with an air lift or cleanout bucket, and check the slurry at the bottom of the hole for compliance with the slurry requirements of Article 16416, Part 2 “Materials.”

G. If the slurry forms a gel before concrete placement, agitate the congealed slurry to liquefaction just before concrete placement and whenever directed.

H. Recover and dispose of all slurry as approved by the Owner’s Representative, and in accordance with all federal, state, and local laws. Do not discharge slurry into or in close proximity to streams or other bodies of water.

3.05 REINFORCING STEEL

A. Completely assemble the cage of reinforcing steel, and place it as a unit immediately before concrete placement. The cage consists of longitudinal bars and lateral reinforcement (spiral reinforcement, lateral ties, or horizontal bands). If overhead obstacles prevent placement of the cage as a single unit, connect individual segments with couplers or by lapping steel as approved.

B. If the shaft is lengthened beyond plan length, extend the reinforcing steel cage as follows, unless directed otherwise:

1. For shafts supporting structures other than bridges, extend the cage to the bottom.

2. For bridge shafts with plan lengths of less than 25 ft., extend the cage to 25 ft. or to the bottom, whichever is shorter.

3. For bridge shafts with plan lengths at least 25 ft. that are lengthened less than 33% of plan length, extending the cage is not necessary.

4. For bridge shafts with plan lengths at least 25 ft. that are lengthened more than 33% of plan length, extend the cage as directed.

C. If the cage does not reach the bottom of the shaft, it may be suspended, or a portion of the longitudinal steel may be extended to support the cage on the bottom of the shaft. Bars used to extend or support the cage may be lap spliced or welded by a qualified welder. Place the extension at the bottom of the shaft.

D. If using spiral reinforcement, tie it to the longitudinal bars at a spacing of at most 24 in., or as required for a stable cage. Do not weld lateral reinforcement to longitudinal bars unless otherwise shown on the plans.

E. Center the reinforcing steel cage in the excavation using approved centering devices. Use enough devices to hold the cage in position along its entire length. Do not use square concrete spacer blocks in cased shafts.

F. Support or hold down the cage to control vertical displacement during concrete placement or extraction of the casing. Use support that is concentric with the cage to prevent racking and distortion of the steel.

G. Check the elevation of the top of the steel cage before and after concrete placement or after casing extraction when casing is used. Downward movement of the steel up to 6 in. per 20 ft. of shaft length and upward movement of the steel up to 6 in. total are acceptable.

H. Maintain the minimum length of steel required for lap with column steel. Use dowel bars if the proper lap length is provided both into the shaft and into the column. Locate and tie all dowel bars into the cage before placing concrete or insert dowel bars into fresh, workable concrete.

I. Locate and tie anchor bolts when required prior to placement of concrete. Use templates or other devices to assure accurate placement of anchor bolts.

3.06 CONCRETE

A. Perform all work in accordance with requirements of Item 03310, "Structural Concrete." Mass concrete placement requirements do not apply to drilled shafts.

B. Form portions of drilled shaft that project above natural ground.

C. Remove loose material and accumulated seep water from the bottom of the excavation before placing concrete. If water cannot be removed, place concrete using underwater placement methods.

D. Place concrete as soon as possible after all excavation is complete and reinforcing steel is placed. Provide workable concrete that does not require vibrating or rodding. Vibrate formed portions of drilled shafts.

E. Place concrete continuously for the entire length of the shaft. For dry shafts of 24 in. or smaller diameter, limit free fall of concrete to 25 ft. Use a suitable tube or tremie to prevent segregation of materials. Use a tube or tremie in sections to provide proper discharge and to permit raising as the placement progresses. For dry shafts over 24 in. diameter, concrete can be allowed to free fall an unlimited distance if it does not strike the reinforcing cage or sides of the hole during placement. When free fall is used, provide a hopper with a minimum 3 ft.-long drop tube at the top of the shaft to direct concrete vertically down the center of the shaft. Do not use a shovel or other means to simply deflect the concrete discharge from the truck.

F. For cased shafts, maintain a sufficient head of concrete at all times above the bottom of the casing to overcome hydrostatic pressure. Extract casing at a slow, uniform rate with the pull in line with the axis of the shaft. Monitor the concrete level in the casing during extraction. Stop the extraction and add concrete to the casing as required to ensure a completely full hole upon casing removal. The elapsed time from the mixing of the first concrete placed into the cased portion of the shaft until the completion of extraction of the casing must not exceed the time for which the concrete maintains a slump of over 4 in. in accordance with Article 16416. Part 2 "Materials." If the elapsed time is exceeded, modify the concrete mix, the construction procedures, or both for subsequent shafts.

G. Cure the top surface and treat any construction joint area in accordance with Item 03310, "Structural Concrete."

3.07 ADDITIONAL REQUIREMENTS FOR SLURRY DISPLACEMENT OR UNDERWATER CONCRETE PLACEMENT METHODS

A. Place concrete on the same day that the shaft is excavated and as soon as possible after all excavation is complete and reinforcing steel is placed. Use an air lift or cleanout bucket of the proper size to clean the bottom of the excavation prior to placing the reinforcing steel cage and concrete. Place concrete through a closed tremie or pump it to the bottom of the excavation. Initially seal the tremie or pump line to positively separate the concrete from the slurry or water. Place concrete continuously from the beginning of placement until the shaft is completed. If using a tremie, keep it full of concrete and well submerged in the previously placed concrete at all times. Raise the tremie as necessary to maintain the free flow of concrete and the stability of any casing used. If using a pump, keep the discharge tube submerged in the previously placed concrete at all times. Place additional concrete to ensure the removal of any contaminated concrete at the top of the shaft. At the completion of the pour, allow the top portion of concrete to flush completely from the hole until there is no evidence of slurry or water contamination. Do not attempt to remove this concrete with shovels, pumps or other means. Level the top of shaft with hand tools as necessary.

B. Use a sump or other approved method to channel displaced fluid and concrete away from the shaft excavation. Recover slurry and dispose of it as approved. Do not discharge displaced fluids into or in close proximity to streams or other bodies of water. For pours over water, provide a collar or other means of capturing slurry and the top portion of concrete flushed from the shaft.

C. If concrete placement is interrupted due to withdrawal of the submerged end of the tremie or pump discharge tube before completion, remove the tube, reseal it at the bottom, penetrate with the tube into the concrete already placed by at least 5 ft., and recharge it before continuing.

D. The elapsed time from the mixing of the first concrete placed until the completion of concrete placement, including extraction of the casing, must not exceed the time for which the concrete maintains a slump of over 4 in. in accordance with Article 416.2, "Materials." If the elapsed time is exceeded, modify the concrete mix, the construction procedures, or both for subsequent shafts.

3.08 TEST LOAD

A. If required, test load shafts in accordance with Item 16405, "Foundation Test Load."

PART 4 MEASUREMENT

4.01 DRILLED SHAFT

A. Drilled shaft foundations will be measured by the foot to the bottom of the shaft.

1. Interior Bents and Piers

a. Shafts will be measured from a point approximately 6 in. below the finished earthwork elevation at the center of each shaft, unless specific elevations or dimensions are indicated on the plans or unless the Owner's Representative directs otherwise to meet unusual conditions. The bent height shown on the plans is for estimating purposes only and does not control the top-of-shaft measurement.

2. Abutment Bents and Retaining Walls

a. Shafts will be measured from the bottom of footing or cap elevation.

3. Other Non-Bridge Structures

a. Shafts will be measured from the top of the shaft.

4.02 BELL FOOTING

A. Bell footings will be measured by the cubic yard of concrete outside of the plan dimensions of the shaft. Bell footings are a plans quantity measurement item. The quantity to be paid is the quantity shown in the proposal. Additional measurements or calculations will be made if adjustments of quantities are required.

4.03 CORE HOLE

A. Core holes will be measured by each core hole drilled.

PART 5 PAYMENT

A. The unit prices bid for the various classifications of drilled shafts and bell footings will be full compensation for excavation; furnishing, placing, and removing casing; furnishing, processing, and recovering slurry; pumping; furnishing, and placing reinforcing steel; furnishing and placing concrete, including additional concrete required to fill an oversize casing or oversize excavation; conducting slump loss tests; backfilling; disposing of cuttings and slurry; and materials, tools, equipment, labor, and incidentals.

B. When the bottom of a drilled shaft is placed at an elevation below plan grade, no direct payment will be made for extra reinforcement placed to support the cage. The extra reinforcement will be considered subsidiary to the price bid per foot of shaft. No extra payment will be made for casings left in place.

C. No payment will be made for "Bell Footing" or "Drilled Shaft" until the concrete has been placed.

5.01 DRILLED SHAFT

A. The work performed and materials furnished in accordance with this Item and measured as provided under "Measurement" will be paid for at the unit price bid for "Drilled Shaft" or "Drilled Shaft (Non-reinforced)" or "Drilled Shaft (Sign Mounts)" or "Drilled Shaft (High Mast Pole)" of the specified diameter, subject to the limitations for overruns authorized by the Owner's Representative given in Section 16416, Part 5, 5.01 A. 1. "Overrun."

1. Overrun

   a. Payment for individual completed shaft lengths up to and including 5 ft. in excess of the maximum plan length shaft, as defined in Section 16416, Part 5, 5.01 A. 2. "Maximum Plan Length Shaft," will be made at the unit price bid per foot of the specified diameter.

   b. Payment for the portion of individual completed shaft length in excess of 5 ft. and up to and including 15 ft. more than the maximum plan length shaft, as defined in this Item, will be made at a unit price equal to 115% of the unit price bid per foot of the specified diameter.

   c. Payment for that portion of individual completed shaft length in excess of 15 ft. more than the maximum plan length shaft, as defined in Section 16416, Part 5, 5.01 A. 2., will be made at a unit price equal to 125% of the unit price bid per foot of the specified diameter.

2. Maximum Plan Length Shaft

   a. Payment described above is subject to the following provisions for extra depth drilling:

      (1). For bridge structures, the maximum plan length shaft is the maximum length shaft, regardless of diameter, for any drilled shaft on that specific bridge.

      (2). For retaining walls, the maximum plan length shaft is the maximum length shaft, regardless of diameter, for any drilled shaft on that specific retaining wall.

      (3). For overhead sign structures, the maximum plan length shaft is the maximum length shaft, regardless of diameter, for any overhead sign structures included in the contract.

      (4). For high mast illumination poles, the maximum plan length shaft is the maximum length shaft, regardless of diameter, for any high mast illumination pole included in the contract.

5.02 BELL FOOTING

A. Bell footings constructed to specified dimensions will be paid for at the unit price bid per cubic yard for "Bell Footings." The quantity to be paid for will be the quantity shown on the plans, unless revised by the Owner's Representative in accordance with "Measurement."

5.03 CORE HOLE

A. Core holes will be paid at $125 each.

END OF SECTION