

## SECTION 31 63 29

### DRILLED CONCRETE PIERS AND SHAFTS

#### PART 1 - GENERAL

##### 1.01 SECTION INCLUDES

- A. Method Test Shaft
- B. Load Test
- C. Excavation
- D. Installation of Concrete Reinforcement
- E. Concrete Placement
- F. Withdrawal of Temporary Steel Casing
- G. Field Quality Control

##### 1.02 MEASUREMENT AND PAYMENT

- A. General: Measurement and payment for drilled shaft foundations will be either by the lump-sum method or by the unit-price method as determined by the listing of the bid item for drilled shaft foundations indicated in the Bid Schedule of the Bid Form.
- B. Lump Sum: If the Bid Schedule indicates a lump sum for drilled shaft foundations, the lump-sum method of measurement and payment will be in accordance with Section 01 20 00, Price and Payment Procedures, Article 1.03, and will include reinforcing steel.
- C. Unit Price: If the Bid Schedule indicates a unit price for drilled shaft foundations, the unit-price method of measurement and payment will be as follows:
  - 1. Measurement:
    - a. Concrete for drilled shaft foundations, of each diameter, including test shaft foundations, will be measured for payment by the linear foot of shaft depth, measured from the cut-off line to the bottom of the shaft.
    - b. Reinforcing steel will be measured separately for payment as specified in Section 03 20 00, Concrete Reinforcing.
    - c. Drilling of shafts (excavation), including drilling of method test shafts, will be measured for payment as individual units (each), per each shaft drilled and accepted.

- d. Load testing of drilled shaft foundations, both compressive and tension load tests, lateral load tests and ultrasonic crosshole testing, will be measured for payment per each load test performed.
  - e. Groundwater control, exploratory drilling, support of excavation for shaft foundations, and steel casing, whether withdrawn or left in place, will not be measured separately for payment; and all costs in connection therewith will be considered incidental to and included with the construction of drilled shaft foundations.
2. Payment: Drilled shaft foundations will be paid for at the indicated Contract unit prices for the computed quantities as determined by the measurement method specified in Article 1.02.C.1.

**1.03 DEFINITIONS**

- A. The words and terms used in these Specifications conform to the definitions given in ACI 336.1.
- B. The terms “drilled shaft” and “cast in drilled hole (CIDH) piles” are used interchangeably.

**1.04 REFERENCES**

- A. International Association of Foundation Drilling (formerly Association of Drilled Shaft Contractors) (ADSC):
  - 1. ADSC Standards and Specifications for the Foundation Drilling Industry.
- B. American Concrete Institute (ACI):
  - 1. ACI 336.1 Specification for the Construction of Drilled Piers
- C. American Society for Testing and Materials (ASTM):
  - 1. ASTM D1143/D1143M Standard Test Methods for Deep Foundations Under Static Axial Compressive Load
  - 2. ASTM D3689/D3689M Standard Test Methods for Deep Foundations Under Static Axial Tensile Load
  - 3. ASTM D3966/D3966M Standard Test Methods for Deep Foundations Under Lateral Loads
  - 4. ASTM D6760 Standard Test Method for Integrity Testing of Concrete Deep Foundations by Ultrasonic Crosshole Testing.

**1.05 SUBMITTALS**

- A. General: Refer to Section 01 33 00, Submittal Procedures, and Section 01 33 23, Shop Drawings, Product Data, and Samples, for submittal requirements and procedures.

- B. Concrete Reinforcement: Provide submittals in accordance with the requirements of Section 03 20 00, Concrete Reinforcing.
- C. Qualifications of Welders and Welding Procedures: Provide submittals in accordance with requirements of Section 03 20 00, Concrete Reinforcing, for reinforcing steel, and with requirements of Section 05 05 22, Metal Welding, for casing steel.
- D. Portland Cement Concrete: Provide submittals in accordance with the requirements of Section 03 05 15, Portland Cement Concrete. Include submittal for tremie concrete equipment and placement method.
- E. Drilling Equipment: Submit description of equipment including but not limited to power rating, torque, downward thrust, and type and size of drilling tools to be used.
- F. Records and Reports: Submit daily reports and shaft record reports or logs as required by ADSC's "Standards and Specifications for the Foundation Drilling Industry," using ADSC formats for forms.

**1.06 QUALITY ASSURANCE**

- A. Construction Standards: Drilled shaft foundations shall be constructed in accordance with applicable requirements of ACI 336.1 and ADSC's "Standards and Specifications for the Foundation Drilling Industry."
- B. Design Criteria:
  - 1. Drilled shaft foundations shall consist of monolithically cast-in-place concrete piles of the sizes indicated.
  - 2. Shaft foundations shall be straight cylindrical shaft type as indicated.
  - 3. Shaft foundations shall extend from the indicated concrete cutoff elevation to the indicated tip elevation.
- C. Tolerances:
  - 1. Maximum variation of the center of any shaft foundation from the required location: 3 inches, measured at the ground surface.
  - 2. Bottom Diameter: minus zero, plus 6 inches, measured in any direction.
  - 3. Maximum variation from plumb: 1 (horizontal):40 (vertical).
  - 4. Maximum bottom level tolerance: plus or minus 2 inches.

D. Inspection of Shaft Excavations:

1. The Contractor shall provide equipment for checking the dimensions and alignment of each shaft excavation. Dimensions and alignment shall be determined jointly by the Contractor and the Engineer. Final shaft depths shall be measured with an appropriate weighted tape measure or other approved method after final cleaning.
2. A minimum of 50 percent of the base of each shaft shall have less than 1/2 inch of sediment at the time of placement of concrete. Maximum depth of sediment or debris at any place on the base of the shaft shall not exceed 1-1/2 inches. Shaft cleanliness will be determined by the Engineer by visual inspection.

**1.07 SEQUENCING AND SCHEDULING**

- A. Unless otherwise permitted by the Engineer, the Contractor shall schedule drilling or excavating, installation of reinforcing steel and concrete placement so that each excavated shaft is poured the same day that the drilling is performed.
- B. Do not permit vibration or excessive wheel loads within the immediate vicinity of any shaft excavation until placement of concrete is complete. Maintain excavation stability at all times.

**PART 2 - PRODUCTS**

**2.01 MATERIALS**

- A. Concrete Reinforcement: Conform to applicable requirements of Section 03 20 00, Concrete Reinforcing, of grades and sizes indicated.
- B. Concrete: Conform to applicable requirements of Section 03 30 00, Cast-in-Place Concrete, and Section 03 05 15, Portland Cement Concrete. Provide class of concrete indicated on the Contract Drawings. Where class of concrete is not indicated, provide Class 3000 concrete.
  1. Prepare separate mix designs for each class of concrete.
  2. Slump for concrete: Slump shall be 5 inches plus or minus 1 inch for dry shafts without temporary casing, and 7 inches plus or minus 1 inch for dry shafts with temporary casing.
- A. Steel Casing:
  1. Where earth wall of drilled shaft is unstable or has a tendency to slough, crumble, or fall away, provide temporary steel casing to stabilize the shaft wall.
  2. Inside diameter of the casing shall be the full diameter of the drilled shaft foundation as indicated, plus or minus 1/2 inch.
  3. Steel casing shall have adequate strength to withstand the pressure of concrete placement without distortion.

4. Inside surfaces of steel casing shall be smooth and coated to facilitate easy lifting and removal during placement of concrete.

## **2.02 EXCAVATING AND DRILLING EQUIPMENT**

- A. Excavating and drilling equipment shall have adequate capacity, including power, torque, and down thrust to excavate a hole of the maximum diameter and to a depth of 20 percent beyond the depth indicated. Excavation and overreaming tools shall be of adequate design, size, and strength to perform the work indicated.
- B. When the material encountered cannot be drilled using conventional earth augers or overreaming tools, special drilling equipment shall be provided, including rock core barrels, rock tools, air tools, and other equipment as necessary to construct the shaft excavation to the size and depth indicated.

## **PART 3 - EXECUTION**

### **3.01 METHOD TEST SHAFTS**

- A. The Contractor shall demonstrate the adequacy of the methods and equipment to be employed for excavating shafts by successfully constructing method test shafts. The number of test shafts shall be as indicated in the Contract Specifications or the Contract Drawings. The method test shafts shall include drilling, reinforcing steel, thread bars, and concrete placement.
- B. Method test shafts shall be positioned away from the drilled shafts in the location indicated or where approved by the Engineer in writing. Method test shafts shall be drilled to the maximum depth of any drilled shaft indicated.
- C. Method test shafts shall be located near existing subsurface exploration data (i.e. a boring or CPT) where the depth of exploration extends to at least to the proposed tip elevation.
- D. Failure to demonstrate the adequacy of methods and equipment shall be sufficient reason for the Engineer to require alterations in equipment and methods by the Contractor to eliminate unsatisfactory results.
- E. Once approval has been given to construct drilled shafts, no change will be permitted in the methods or equipment used to construct the satisfactory method test shaft without the written approval of the Engineer.

### **3.02 LOAD TESTS**

- A. Requirements:
  1. The Contractor shall perform compression load tests, tension load tests, and lateral load tests as required to determine whether or not the shafts can carry and withstand the imposed loads. Tests shall be performed on the method test shafts. Except for shafts required for testing, additional shaft construction will not be permitted until the load tests are completed.

2. Load test requirements shall be as indicated in the Contract Specifications or Contract Drawings.
  3. The Contractor shall provide all equipment and apparatus as required to conduct the tests.
  4. The Contractor shall install, remove, relocate, and reinstall weights and components as necessary to perform and complete the tests.
  5. Tests can be conducted as soon as practicable after the concrete in each drilled shaft has attained the specified 28-day compressive strength, but not until at least 10 days have elapsed after placing the concrete.
- B. Compression Load Tests: Tests shall be performed in accordance with ASTM D1143/D1143M. Method of load test shall follow “Quick Load Test Method for Individual Piles” as specified in ASTM D1143/D1134M, Section 5.6. The maximum test load shall be at least 2.5 times the design load as prescribed by the Engineer. Apply the load in increments equal to 10 percent of the maximum test load, with a constant time interval between increments of 5 minutes. Maintain the maximum test load for not less than 15 minutes, unless the shaft has failed as determined by the Engineer. Remove the test load in increments equal to 25 percent of the maximum test load, with a constant time interval between increments of 5 minutes.
- C. Tension Load Tests: Tests shall be performed in accordance with ASTM D3689/D3689M. Method of load test shall follow “Quick Load Test Method for Individual Piles” as specified in ASTM D3689/D3689M, Section 7.7. The maximum test load shall be at least twice the design load as prescribed by the Engineer. Apply the load in increments equal to 10 percent of the maximum test load, with a constant time interval between increments of 5 minutes. Maintain the maximum test load for not less than 15 minutes, unless the shaft has failed as determined by the Engineer. Remove the test load in increments equal to 25 percent of the maximum test load, with a constant time interval between increments of 5 minutes.
- D. Lateral Load Tests: Tests shall be performed in accordance with ASTM D3966/D3966M. Method of load test shall follow “Standard Loading Procedures” as specified in ASTM D3966/D3966M, Section 6.1.
1. Drilled shafts and CIDH piers/piles capacity to resist wind loading. Applies the lateral load until the test shaft/pier/piles displaces 0.25 inches horizontally.
  2. Drilled shafts and CIDH piers/piles capacity to resist Design Basis Earthquake (DBE). Applies the lateral load until the load-displacement curve first exhibits non-linear/bi-linear (change of slope) displacements from the latest load testing.
- The drilled shaft and CIDH pier/piles capacity to resist DBE shall be determined by the structural engineer responsible for the design of the structures in accordance with BART Standard Specifications, Facility Design, Structural, Foundations.

3. Drilled shafts and CIDH piers/piles capacity to resist Maximum Considered Earthquake (MCE) or other Extreme Limit States. Applies the lateral load until load-displacement curve first exhibits zero slope displacement (plateau) from the lateral load testing.

The drilled shafts and CIDH piers/piles capacity to resist MCE shall be determined by the structural engineer responsible for design of the structures in accordance with BART Standard Specifications, Facility Design, Structural, Foundations.

4. For drilled shafts and CIDH piers/piles supporting building structures, the lateral pile load capacity shall be determined and verified with the lateral load testing specified in Chapter 18 of CBC, Section 1810, Deep Foundations.

### 3.03 EXCAVATION

#### A. General:

1. Excavate for shaft foundations by drilling or by other methods, as approved by method test shafts, to advance the excavation to the required bottom elevation as indicated on the Contract Drawings or as directed by the Engineer. Avoid over excavation. Excavation shall be performed through whatever materials are encountered to the dimensions, depths, and tolerances indicated. Bottoms of excavations shall be level and flat.
2. When required by the Engineer, drill and core an exploratory hole, approximately 3 to 4 inches in diameter, to a depth of 15 feet below the excavation invert and backfill with grout.
3. Protect excavated walls with temporary steel casing as necessary to prevent cave-ins, displacement of the surrounding earth, water incursion, injury to personnel, and damage from construction operations. Maintain indicated neat lines of excavation for cased areas.
4. Make bottom surfaces level within the tolerances specified herein. Remove loose material, debris, and muck with cleaning buckets.

#### B. Ground Water Control:

1. Notify the Engineer immediately when ground water is encountered.
2. Suitable steel casings shall be furnished and placed when necessary to control water. Drilling mud or chemical stabilizers shall not be used unless permitted by the Engineer.

- C. Inspection: After completion of excavation and prior to placement of reinforcing steel, the condition of the excavation will be inspected by the Engineer. Use clean-out buckets or air-lifts to remove any slough or other loose material from the shaft prior to placing reinforcing steel and concrete. An accumulation of soil or rock in the bottom of the excavation will not be permitted.

**3.04 INSTALLATION OF CONCRETE REINFORCEMENT**

- A. Where it is not practicable to deliver the cage assembly to the jobsite as a complete unit ready for installation, make the remaining connections or splices, as indicated on the approved Shop Drawings, at-grade prior to lowering the assembly into the hole.
- B. Lower reinforcing steel into the hole in such a manner as to prevent damage to the walls and cause sloughing. Place and tie or clip symmetrically about the axis of the shaft. Use centering devices, securely attached to the cage, to clear the shaft walls and to maintain the cage in place throughout the concrete placement.
- C. Set reinforcing steel at required location and elevation prior to concrete placement. Hold and support steel such that it does not move during concrete placement.
- D. Check the elevation of top reinforcing steel before and after concrete placement. Make adjustments if steel cage position is not maintained.
- E. Check depth of hole using a weighted tape before and after placement of the reinforcing steel. If more than 1 inch to the bottom of the hole is lost, remove cage and remove slough at bottom of hole.

**3.05 CONCRETE PLACEMENT**

- A. Place concrete in dry excavations whenever practicable. Use all practicable means to obtain a dry excavation before and during concrete placement.
- B. Concrete shall be placed as soon as possible after reinforcing steel installation. Concrete placement shall be continuous from the bottom to the top elevation of the shaft. Concrete placement shall continue until good quality is evident at the top of the shaft. Concrete shall be placed with a tremie pipe connected to a concrete boom truck.
- C. Infiltration of groundwater at or near the bottom of the hole exceeding ¼ inch rise per minute will be considered a wet placement.
- D. Wet Concrete Placement
  - 1. Fill hole with water or slurry to the natural water level to equalize the hydraulic head inside and outside the shaft excavation before starting concrete placement. Use only concrete mix designed for tremie placement.
  - 2. Tremie shall be constructed such that it is watertight and will readily discharge concrete. The tremie shall be of sufficient length to permit the discharge end to be immersed in concrete at all times.
  - 3. A plug or similar device shall be used to separate the concrete from the fluid in the hole until pumping begins. Once concrete placement begins, the tip of the tremie pipe shall be maintained to prevent reentry of the slurry into the pipe.

4. Flow of concrete shall be continuous and concrete in tremie shall have sufficient capacity to maintain a positive pressure differential at all times to prevent water or slurry intrusion into the shaft concrete.

### **3.06 WITHDRAWAL OF TEMPORARY STEEL CASING**

- A. Where temporary steel casings are used to support the excavation walls, withdraw the casing as the concrete is being placed, unless otherwise indicated or unless the Engineer requires that the casing be permanently grouted in place. Remove the steel casing in such a manner so that the lower edge of the steel liner will always remain a minimum of 5 feet below the surface of the concrete as placed to prevent water from entering the casing from the bottom. Vibrate concrete during withdrawal of the steel casing.

### **3.07 FIELD QUALITY CONTROL**

- A. Inspections and Tests: The Contractor shall perform inspections and tests of concrete as specified in Section 03 05 15 - Portland Cement Concrete.
- B. For large diameter drilled shafts (3 feet or larger in diameter) and for all drilled shafts or CIDH piles/piers encountering ground water, the Contractor is required to perform ASTM D6760, Ultrasonic Crosshole Testing to confirm the homogeneity and integrity of all of the drilled shafts and CIDH piers/piles. If any of the tested shaft or CIDH pile/pier fails to meet the testing requirements, the Contractor has to remedy the defects and to submit a plan to the Engineer for approval before proceeding, at no additional cost to BART.
- C. Records and Reports: Keep a record, on an approved form, for each drilled shaft foundation installed. Record on the form the location, dimensions, elevations of top and bottom, depth of stratum penetration, condition of bottom of excavation, concrete placement data, a continuous record of actual concrete volume placed versus theoretical volume, and any other data called for on the approved report form or pertinent to the foundation.

**END OF SECTION 31 63 29**