c. *Required Fluid Level.* During construction, maintain the level of mineral-polymer blended slurry in the excavation at a level not less than 4 ft (1.2 m) above the highest expected piezometric pressure head along the depth of the shaft. Maintain the level of polymer slurry at a level not less than 6 ft (1.8 m) above the highest expected piezometric pressure head along the shaft.

3. *Water as a Drilling Fluid.* Prior to placing concrete in a shaft excavation, take slurry samples using an approved sampling tool designed to sample over a depth range of 12 in. or less. Extract slurry samples from the base of the shaft and at intervals not exceeding [10 ft (3 m)] up the slurry column in the shaft, to verify the shaft has the acceptable values for density, viscosity, pH and sand content specified in 805-03(J)(1) and 805-03(J)(2) if polymer slurries are used.

   When slurry samples are found to be unacceptable, take whatever action is necessary to bring the slurry within specification requirements. Do not pour concrete until the slurry in the hole is re-sampled and test results produce acceptable values.

   If approved by the Engineer, the Contractor may use water as the drilling fluid. Ensure water used as the drilling fluid meets all requirements specified in Table 805.3-1, except that the maximum density shall not exceed 70 lb/ft^3 (11 kN/m^3) and the minimum density values indicated in Table 805.3-1 do not apply.

K. *Inspecting Excavated Shafts.* Provide equipment for checking the dimensions and alignment of each shaft excavation. Determine the dimensions and alignment under the supervision of the Engineer. Measure final shaft depths with a suitable weighted tape or other approved methods after final cleaning.

   Ensure that the following requirements are met, as applicable:

   1. A minimum of 50 percent of the base of each shaft has less than $^1/_2$ in. (12 mm) of sediment.

   2. The maximum depth of sediment or debris at any place on the base of the shaft does not exceed $1^1/_2$ in. (38 mm).

   3. For dry excavations, the maximum depth of water does not exceed 3 in. (75 mm) prior to the concrete pour.

   4. For dry shafts, the sidewalls are visually free of cuttings that may have been smeared on the walls during the removal and insertion of drilling tools.

      The Engineer will determine shaft cleanliness by visual inspection for dry shafts or other methods deemed appropriate for wet shafts.

L. *Construction Tolerances.* Construct drilled shafts with the following tolerances:

   1. Maintain the drilled shaft position within 3 in. (75 mm) of the plan position in the horizontal plane at the plan elevation for the top of the shaft.

2. Limit the variation of the vertical alignment of the shaft excavation from the plan alignment to no more than $^1/_4$ in./ft (20 mm/m) of depth. Limit the variation of the alignment of a battered shaft excavation to no more than $^1/_2$ in./ft (40 mm/m) of distance along the axis of the shaft from the prescribed batter.

3. Keep the top of the reinforcing steel cage within 6 in. (150 mm) above and 3 in. (75 mm) below plan position.

4. All casing diameters shown on plans refer to outside diameter (O.D.) dimensions. Ensure dimensions of casings meet American Pipe Institute tolerances applicable to regular steel pipe. When approved, the Contractor may provide a casing larger in diameter than that shown in the plans.

5. Excavate the bells to the bearing area and height shown on the plans. Ensure the actual diameter of the bells does not exceed three times the specified shaft diameter. The Contractor may vary other plan dimensions to accommodate equipment with the Engineer's approval.

6. Ensure the top elevation of the shaft is within plus 1 in. (25 mm) or minus 3 in. (75 mm) of the plan top of shaft elevation.

7. Use excavation equipment and methods to ensure the completed shaft excavation has a planar bottom. Ensure the cutting edges of excavation equipment are normal to the vertical axis of the equipment within a tolerance of $\pm^3/_8$ in./ft (30 mm/m) of diameter.

The Engineer will consider drilled shaft excavations and completed shafts not constructed within the required tolerances as unacceptable. Furnish materials and perform the work necessary, including engineering analysis and redesign, to correct out-of-tolerance drilled shaft excavations to the satisfaction of the Engineer, at no cost to the Agency and without an extension to the completion date of the project.

M. *Constructing and Placing Reinforcing Steel Cage.* Immediately after the Engineer inspects and approves the shaft excavation, but prior to placing concrete, assemble and place as a unit the reinforcing steel cage, consisting of longitudinal bars, ties, cage stiffener bars, spacers, and centralizers. Remove loose material from the bottom of the excavation before placing reinforcing steel cage. Remove internal stiffeners as the cage is placed in the borehole so as not to interfere with the placement of concrete.

Tie and support the reinforcing steel so that it remains within tolerance of its intended position, as specified in Subsection 805.3(L). Use concrete spacers or other approved noncorrosive spacing devices at intervals not exceeding 10 ft (3 m) along the shaft to ensure concentric spacing for the entire cage length. Use a minimum of one spacer per 30 in. of circumference of cage with a minimum of three at each level. Construct spacers of approved material equal in quality and durability to the concrete specified for the shaft. Construct spacers of adequate dimensions to ensure a minimum of 3-in. (75-mm) annular space between the outside of the reinforcing cage and the side of the excavated hole. Provide approved cylindrical concrete feet (bottom supports) to ensure that the bottom of the cage is maintained at the proper distance above the base.

N. Check the elevation of the top of the steel cage before and after placing concrete. The Engineer will consider drilled shafts to be defective if the upward displacement of the rebar cage exceeds 2 in. (50 mm) or if the downward displacement exceeds 6 in. (150 mm) per 20 ft (6 m) of shaft length. Correct defective shafts to the satisfaction of the Engineer at no cost to the Agency. Do not construct additional shafts until the rebar cage support is modified in a manner satisfactory to the Engineer.

O. *Placing Concrete.* Place concrete as soon as possible after placement of the reinforcing steel cage. Continuously place the concrete in the shaft from the bottom to the top elevation of the shaft. Continue to place concrete after the shaft excavation is filled until good quality concrete is evident at the top of the shaft. Place concrete either by free fall (for dry holes only) or through a tremie or concrete pump. Ensure concrete placed by free fall falls directly to the base without contacting either the rebar cage or hole sidewall. The Contractor may use drop chutes to direct concrete to the base during free fall placement. Inspect hole for debris after placement.

P. Limit the time spent placing concrete to the maximum allowable elapsed time for placing concrete as determined by the slump loss test. The elapsed time for placing drilled shaft concrete includes the concrete mixing and transit time, the concrete placement time, the time required to remove any temporary casing that causes the concrete to flow into the space previously occupied by the casing, and the time required to insert any required column steel, bolts, weldments, etc. The allowable elapsed time is defined as the maximum elapsed time within which the concrete will maintain a slump of at least 5 in. (125 mm). Only use admixtures, such as water reducers, plasticizers, and retarders, in the concrete mix if specified in the contract documents. Maintain a minimum slump of 5 in. (125 mm) throughout the elapsed time. Use materials to produce and maintain the required slump through the elapsed time. Prior to beginning drilled shaft construction, provide slump loss tests results by an approved testing laboratory that demonstrate to the Engineer that the concrete will maintain a 5 in. (125 mm) or greater slump for the anticipated elapsed time. Conduct slump loss tests using concrete and ambient temperatures appropriate for the site conditions.

1. *Tremies.* The Contractor may use tremies to place concrete in either wet or dry holes. Use tremies consisting of a tube of sufficient length, weight, and diameter to discharge concrete at the shaft base elevation. Ensure that the tremie contains no aluminum parts that will have contact with the concrete. Ensure that the inside diameter of the tremie is at least 6 times the maximum size of aggregate used in the concrete mix, but not less than 10 in. (250 mm). Keep the inside and outside surfaces of the tremie clean and smooth to allow both flow of concrete and unimpeded withdrawal during concreting. Ensure that the wall thickness of the tremie is adequate to prevent crimping or sharp bends that could restrict concrete placement.

   Ensure that the tremie used for wet excavation concrete placement is watertight and of enough weight that will not float and can reach the bottom of the excavation by its own weight. Do not begin underwater or under-slurry placement until the tremie is placed to the shaft base elevation. Keep the concrete separate from the water or slurry prior to its discharge. The Contractor may use valves, bottom plates, or plugs for this purpose if the

concrete discharge can begin within one tremie diameter of the base of the drilled shaft. The Contractor may either remove plugs from the excavation or use plugs of a material, approved by the Engineer that will not cause a defect in the shaft if not removed. Construct the discharge end of the tremie to allow free radial flow of concrete during placement operations. Ensure that the tremie discharge end is immersed in at least 5 ft (1.5 m) of concrete at all times after starting the flow of concrete. Ensure the flow of concrete is continuous. Maintain the level of concrete in the tremie above the level of slurry or water in the borehole at all times to prevent water or slurry intrusion into the shaft concrete.

If, at any time during the concrete pour, the tremie line orifice is removed from the fluid concrete column and discharges concrete above the rising concrete level, consider the shaft defective. In such case, remove the reinforcing cage and concrete, complete any necessary sidewall removal directed by the Engineer, and repour the shaft. Perform this corrective work at no cost to the Agency.

2. *Pumped Concrete.* The Contractor may use concrete pumps and lines for concrete placement in either wet or dry excavations. Provide pump lines of a minimum 4-in. (100-mm) diameter. Construct lines with watertight joints. Do not place concrete until the pump line discharge orifice is at the shaft base elevation.

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

   Ensure the discharge orifice remains at least 5 ft (1.5 m) below the surface of the fluid concrete. When lifting the pump line during concreting, temporarily reduce the line pressure until the orifice has been repositioned at a higher level in the excavation.

   If, at any time during the concrete pour, the pump line orifice is removed from the fluid concrete column and discharges concrete above the rising concrete level, consider the shaft defective. In such case, remove the reinforcing cage and concrete, complete any necessary sidewall removal directed by the Engineer, and repour the shaft. Perform this corrective work at no cost to the Agency.

3. *Drop Chutes.* The Contractor may use drop chutes to direct placement of free-fall concrete in excavations where the maximum depth of water does not exceed 3 in. (75 mm). Do not perform free-fall placement in wet excavations. The Contractor may use drop chutes consisting of a smooth tube of either one-piece construction or sections that can be added and removed. Alternatively, the Contractor can use as a drop chute a hopper with a short tube to direct the flow of concrete. Concrete may be placed either through the hopper at the top of the tube or through side openings as the drop chute is retrieved during concrete placement. If 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 reduce the rate of concrete flow into the excavation, or both.

If caving or sloughing of the borehole walls occurs during free-fall placement of concrete, consider the shaft defective. In such case, remove the reinforcing cage and concrete, complete any necessary sidewall removal directed by the Engineer, and repour the shaft. Perform this corrective work at no cost to the Agency. If concrete placement cannot be satisfactorily accomplished by free fall in the opinion of the Engineer, use either tremie or pumping techniques for the pour.

Q. *Nondestructive Evaluation.* When called for in the contract documents or when requested by the Engineer, evaluate the structural integrity of completed drilled shafts using nondestructive testing techniques, such as (a) downhole tests conducted in access tubes, including crosshole acoustic tests and backscatter gamma ray (gamma-gamma) tests, (b) sonic echo tests, or (c) thermal integrity profiling (TIP). The Agency will specify the type of testing, if any, to be used and the specific shafts on which to perform the testing. Perform the required testing and submit reports of the testing to the Engineer in a timely manner. Conduct testing after the concrete has cured for at least 72 h. Perform CSL in accordance with ASTM D6760. When required, perform Gamma-Gamma Logging (GGL) testing in accordance with Caltrans CTM 233 test method. When TIP is specified, conduct this test between 24 h and 72 h after concrete placement, in accordance with ASTM D7949.

Employ a registered professional engineer, who has been qualified by the State, to perform, evaluate, and report the tests. Submit the test report on any given shift to the Engineer within 3 working days of performing the test on that shaft. Submit a signed and sealed report to the Engineer that includes the testing and analysis results. Meet the reports requirement specified in the ASTM and CTM methods indicated above. In addition, include in the report a professional opinion that states whether the drilled shaft is free from integrity defects and whether the Specialty Engineer submitting the report recommends the shaft for acceptance.

R. Within 3 working days of receiving the test report, the Engineer will evaluate and analyze the results and provide the Contractor with a response regarding the acceptability of the shaft that was tested.

The Contractor may continue to construct drilled shafts before receiving the Engineer's notice of acceptance of the tested shaft or shafts. If, however, the Engineer finds the tested shaft(s) to be unacceptable, repair the unacceptable shaft to the satisfaction of the Engineer and at no cost to the Agency. With regard to shafts constructed after the unacceptable shaft was constructed and tested, the Contractor may either prove their acceptability to the satisfaction of the Engineer, at no cost to the Agency, or will cease all drilled shaft construction until a new construction procedure has been proposed by the Contractor and accepted by the Engineer. In this latter case, repair those drilled shafts constructed after the unacceptable shaft to the satisfaction of the Engineer and at no cost to the Agency. Submit a written plan to the Engineer regarding the repair of defects and revisions to construction procedures. If the plans involve changes to the structural design of the shafts or shaft caps, or to the geometry of the shafts, engage a registered professional engineer to perform any necessary redesign at no cost to the Agency.

The Engineer may require testing of additional shafts. If the testing of the additional shaft(s) indicates defects in these shafts, bear the costs of testing and repairing the defective shafts. If the testing reveals no defects, the Agency will bear the costs of testing the non-defective shaft.

1. *Tests in Access Tubes.* Place access tubes for crosshole acoustic or gamma-gamma logging or Thermal Integrity Profiling (TIP) on each reinforcing cage designated in the contract documents in the position and at the frequency shown on the plans. Provide access tubes for crosshole acoustic logging of Schedule 40 steel pipe, with at least a $1^1/_2$-in. (38-mm) inside diameter, meeting ASTM A53/A53M, Grade A or B, Type E, F, or S. For gamma-gamma testing, provide access tubes of Schedule 40 polyvinyl chloride (PVC) pipe with an inside diameter of at least 2 in. (50 mm). For TIP tests provide steel access tubes as specified for CSL above, or use thermal wires when these are required in the plans. Install access tubes full length from the tip of shaft to a point high enough above top of shaft to allow testing, but not less than 30 in. above the top of the drilled shaft, ground surface or water surface, whichever is higher. Equally space tubes around circumference of drilled shaft. Securely tie access tubes to the inside of the reinforcing cage and align tubes to be parallel to the vertical axis of the center of the cage.

   Ensure that the access tubes are free from loose rust, scale, dirt, paint, oil and other foreign material. Couple tubes as required with threaded couplers, such that inside of tube remains flush. Seal the bottom and top of the tubes with threaded caps. The tubes, joints and bottom caps shall be watertight. Seal the top of the tubes with lubricated, threaded caps sufficient to prevent the intrusion of foreign materials. Stiffen the cage sufficiently to prevent damage or misalignment of access tubes during the lifting and installation of the cage.

   Insert simulated or mock probes in each access tube prior to concreting to ensure the serviceability of the tube. Fill access tubes with clean potable water and recap prior to concreting. Repair or replace any leaking, misaligned or unserviceable tubes as in a manner acceptable to the Engineer prior to concreting. Immediately after concreting, check the water levels in the access tubes and refill as necessary.

   Prior to beginning downhole logging or testing, ensure that the test probes can pass through every tube to the bottom. If a tube is obstructed, core a hole, at no cost to the Agency, within the drilled shaft near the obstructed tube to the depth of the obstructed tube that is large enough to accommodate the probe for the full length of the hole. Obtain the Engineer's approval of the coring equipment, coring procedure, and location of the core hole prior to beginning the coring process. Use a coring method that provides for complete core recovery and minimizes abrasion and erosion of the core. Place the core hole at a position in the shaft that will not damage the reinforcing steel in the shaft. Identify the core hole, and any voids or defects, on a log and submit to the Engineer. Preserve cores and make available for inspection by the Engineer. Treat the core hole as an access tube and begin downhole testing. If a defect is observed, pay for coring costs and repair the shaft at no cost to the Agency. If no defects are observed, the Agency will pay for coring costs.

After completing all tests involving access tubes, fill the access tubes and core holes with grout having strength properties equivalent to or better than those of the drilled shaft concrete.

2. *Sonic Echo Tests.* The Contractor may perform sonic echo (pulse-echo) tests instead of downhole tests involving access tubes at the discretion of the Engineer. Ensure equipment and procedures used for sonic echo tests have a resolution capable of detecting defects occupying no more than 30 percent of the cross-sectional area of the drilled shaft and that are no greater than 6 in. (150 mm) thick. Indicate this resolution in the test report submitted to the Engineer. It is not necessary to construct access tubes prior to constructing the drilled shaft. If a defect is observed in a sonic echo test, pay for all testing costs and repair the shaft at no cost to the Agency. If no defects are observed, the Agency will pay for coring costs.

S. *Drilled Shaft Load Tests.* When the contract documents include static load testing of shafts, complete all load tests before constructing any production drilled shafts. Allow 5 working days from the last load test for the Engineer to analyze the load test data and make final determinations of base elevations. Do not construct production shafts until the Engineer provides authorization to proceed. Perform load tests at the locations shown on the plans or as directed by the Engineer. Unless otherwise specified, apply to the load test shafts the maximum test load corresponding to failure, as defined as a deflection of the shaft head equal to 5 percent of the shaft diameter.

Do not begin static load testing until the concrete has attained a compressive strength of 3,400 psi (23.4 MPa) as determined from cylinder breaks. Load test drilled shafts in the order directed by the Engineer. Perform static load tests according to ASTM D1143/D1143M (compression test quick test method) and ASTM D3966/D3966M (lateral test) or as modified herein. Supply the equipment necessary to conduct the static test, including equipment to measure loads and deflections. Ensure the loading frame apparatus can safely accommodate the maximum load to be applied.

Notify the Engineer within 10 calendar days of contract award of the load testing schedule. If nondestructive testing is to be performed as specified in Subsection 805.3(Q), ensure the schedule allows at least 1 working day for the Engineer's analysis of the nondestructive testing results prior to load testing.

Provide load cells of adequate size to measure the maximum load applied during the drilled shaft load tests. Equip the load cell with an adequate readout device. Before beginning load testing, furnish a certificate of calibration for the load cell from an approved testing laboratory. Ensure the calibration was performed for the range of the proposed loading within the two months preceding the load tests. Ensure the certified accuracy of the load cell is within 1 percent of the true load.

After testing is complete, cut off the test shafts (and any reaction shafts) at an elevation 2 ft (0.6 m) below the finished ground surface. The portion of the shafts cut off and removed are the property of the Contractor.

805.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1 and as follows:

A. The Engineer will measure drilled shafts by the length in ft (m) from the plan top of shaft elevation to the final bottom of shaft elevation. The Engineer will not separately measure excavation or blasting.

B. The Engineer will determine quantity of concrete for bells based on the volume of concrete outside the plan dimensions of the shaft.

C. The Engineer will measure trial shafts by the length in ft (m) from the existing ground surface elevation at the center of the trial shaft hole prior to drilling to the authorized bottom elevation of the hole.

D. The Engineer will measure permanent casing by the length in ft (m) of each size casing used, as measured along the casing from the top of the shaft elevation or the top of casing, whichever is lower, to the bottom of the casing.

E. The Engineer will measure exploration holes by the length in ft (m) from the bottom of the shaft to the bottom of the exploration hole.

F. The Engineer will measure load tests by the number of load tests completed according to the specified loading procedures and to the designated maximum load shown on the plans. Payment will include all costs related to the performance of the load test and for the reporting of procedures and results.

G. The Engineer will measure nondestructive evaluation tests on a lump sum basis per shaft tested. The lump sum payment will include costs for mobilization, testing, analysis, and reporting.

H. The Engineer will quantify the number of hours of work per obstruction, as designated by the Engineer, required to remove the obstruction and resume excavation.

805.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) Drilled shaft, furnished (size ___)	ft (m)
(B) Bells	cy^3 (m^3)
(C) Trial shafts, furnished (size ___)	ft (m)
(D) Trials bells, furnished (size ___)	cy^3 (m^3)
(E) Permanent casing (size ___)	ft (m)
(F) Exploration holes	ft (m)
(G) Load test	each
(H) Nondestructive evaluation	lump sum per drilled shaft
(I) Obstructions	h

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

SECTION 806
GROUND ANCHORS

806.1 DESCRIPTION

Design, furnish, install, test, and stress permanent cement-grouted ground anchors that will develop the load-carrying capacity indicated on the plans.

806.2 MATERIALS

Provide materials as specified in Section 718.

806.3 CONSTRUCTION

A. *Submittals:*

1. *Contractor Qualifications.* At the time of bid, submit the following information to demonstrate the qualifications of the Contractor:

   a. a list containing at least [5] projects completed in the last [5] years on which the Contractor designed and installed ground anchors;

   b. the names and contact information of Agency's representatives who can verify the Contractor's participation on the listed projects;

c. name and experience record, indicating a minimum of three years of experience, of the engineer proposed to design and oversee the construction of the anchor system; and

d. names and experience records, indicating a minimum of one year experience in installing permanent ground anchors with the Contractor's organization, of the onsite superintendent and drill operators.

Do not substitute any of the proposed individuals without the written approval of the Engineer. The Engineer will approve or reject the Contractor's qualifications and staff within 15 working days after receiving the submission. Do not start work on the anchored wall system or order materials until the Engineer approves the qualifications submittal. The Engineer may suspend the work if the Contractor substitutes unqualified personnel for the approved personnel during construction. If work is suspended due to the substitution of unqualified personnel, assume liability for additional costs resulting from the suspension of work.

2. *Design and Working Drawings.* Submit working drawings and calculations to the Engineer for review and approval at least 30 working days before the start of the ground anchor work. Include the following information in the submittal:

   a. A ground anchor schedule providing:

      i. Ground anchor number;

      ii. Ground anchor design load;

      iii. Type and size of tendon;

      iv. Minimum total anchor length;

      v. Minimum bond length;

      vi. Minimum tendon bond length; and

      vii. Minimum unbonded length.

   b. A drawing of the ground anchor tendon and the corrosion protection system including details for the following:

      i. Spacers and their location;

      ii. Centralizers and their location;

      iii. Unbonded length corrosion protection system;

      iv. Bond length corrosion protection system;

      v. Anchorage and trumpet; and

      vi. Anchorage corrosion protection system.