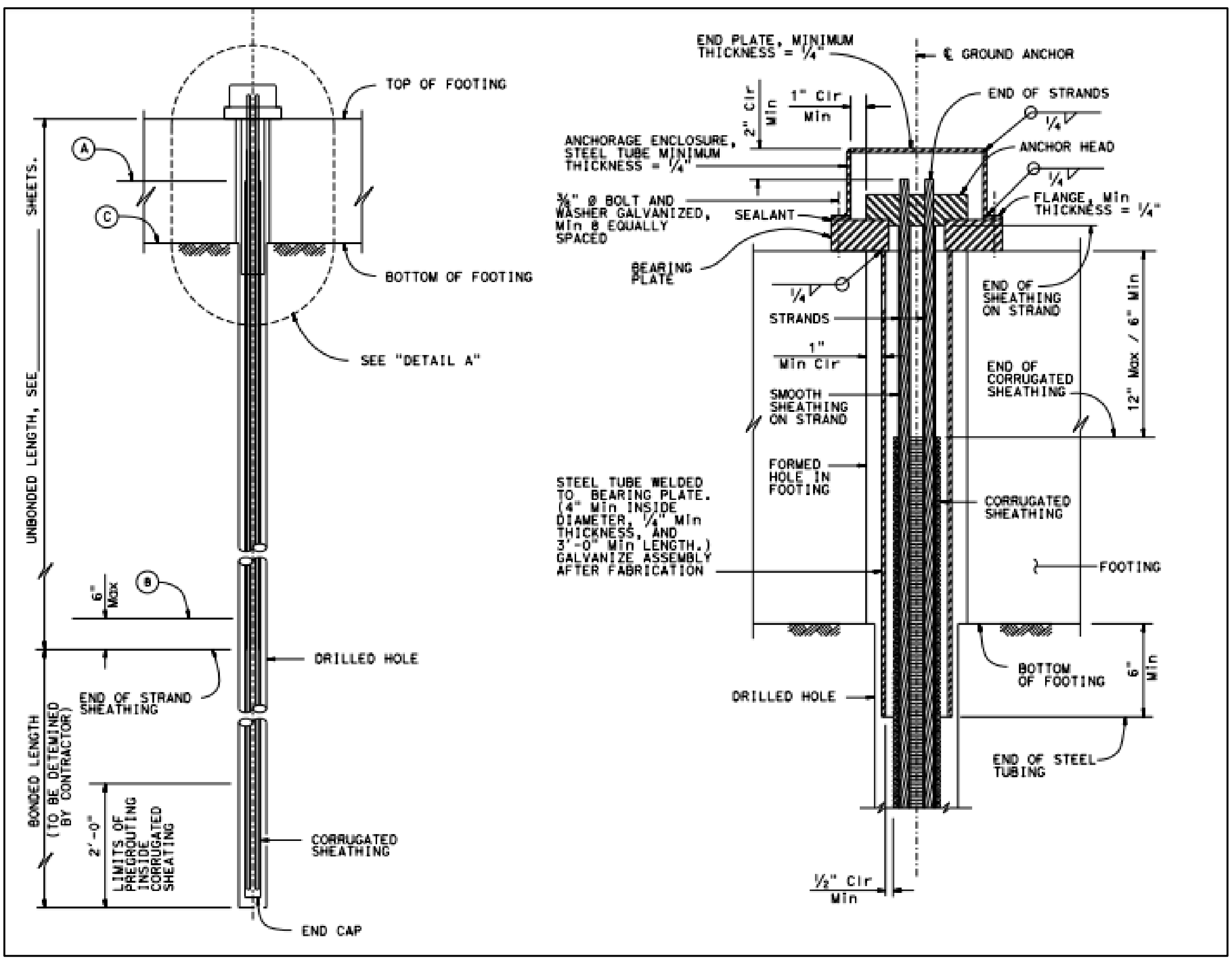
Vertical Ground Anchors

A vertical ground anchor, also referred to as "tie-downs," is a structural element installed in soil or rock that is used to transmit an applied tensile load into the ground. Vertical ground anchors can be used to resist uplift forces at bridge foundations and earth retaining structures such as a Caltrans Type 7 retaining wall. The intent of this module is to provide geotechnical design guidelines when vertical anchors are to be used as part of foundation support elements for bridges and retaining structures.

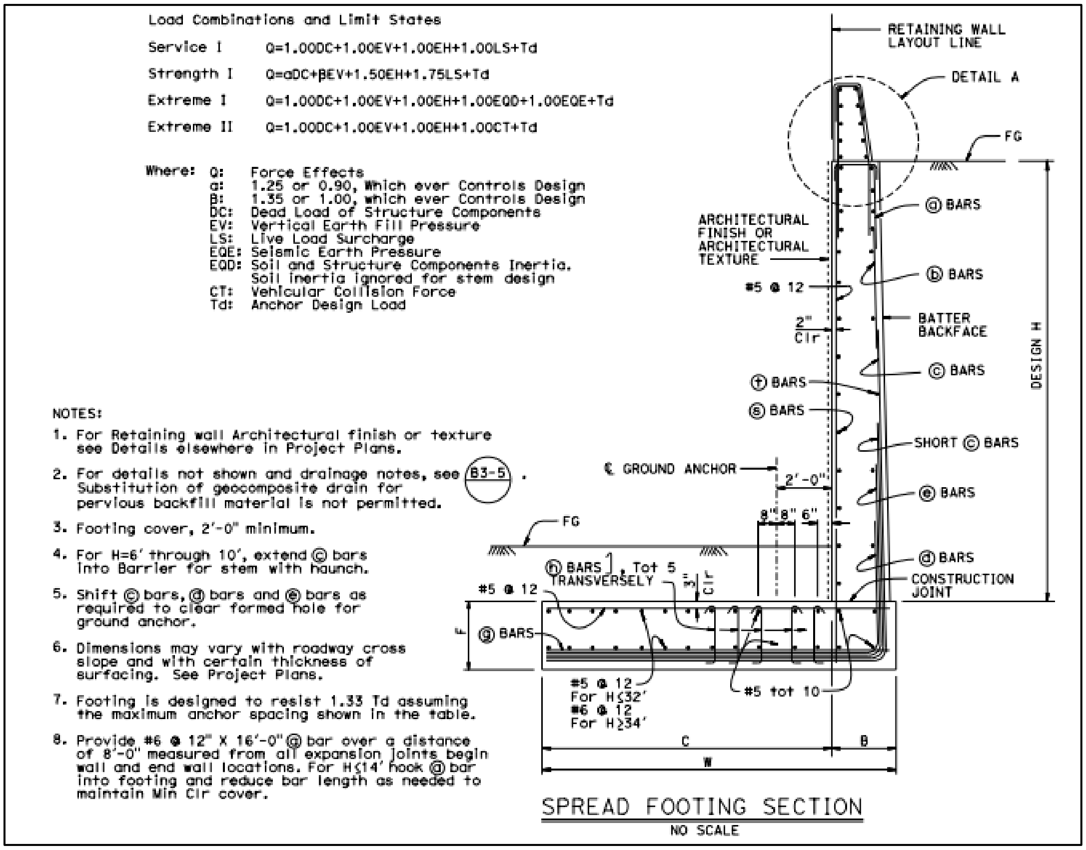
Vertical grouted ground anchors are installed in grout filled drill holes. The basic components of a grouted ground anchor include the anchorage system, tendon, and grout. The anchorage system generally consists of a bearing plate, trumpet (steel tube welded to the bearing plate), and an anchor head with wedges (or threaded nut). The tendon can be either multiple-wire strands or a high strength bar that transmits the tensile force. The grout transfers the tensile force from the tendon to the ground. Figure 1 shows the components of a vertical ground anchor.

Figure 1: Vertical Ground Anchor Details (from Caltrans XS Sheet No. xs12-030-1)



Vertical ground anchors can be used for foundation elements subject to uplifting or overturning. For example, vertical ground anchors are utilized in Caltrans Type 7 retaining wall design to resist overturning of the wall. Figure 2 shows details of a Caltrans Type 7B retaining wall.

Figure 2: Type 7B Retaining Wall (from Caltrans XS Sheet No. xs14-375-1)



Design Methods and Requirements

When considering the use of vertical ground anchors in foundation design, refer to the following references:

- AASHTO LRFD BDS with California Amendments (AASHTO LRFD BDS)
- Section 46 of the Standard Special Provisions (SSP)
- *Geotechnical Engineering Circular N0. 4, Ground Anchors and Anchored Systems* (FHWA IF-99-015)

Roles and Responsibilities

The typical responsibilities of the structure designer (SD) and Geoprofessional (GP) for vertical ground anchor design are listed in Table 1.

Table 1: Responsibilities for Vertical Ground Anchor Design

Structure Designer (SD)	Geoprofessional (GP)
• Determine the unfactored design load (DL). • Determine seismic design load (T_s). • Determine the factored design load: for bridge foundation (FDL); for Caltrans Type 7 wall (T_d). • Determine the factored test load: for bridge foundation (FTL); for Caltrans Type 7 wall (T_p). • Determine the lock-off load: for bridge foundation (LL); for Caltrans Type 7 wall (T_o).	• Specify the unbonded length. • Specify the pullout resistance factor to be used in design. • Request extended creep testing, if needed. • Specify the number of performance tests* required per footing/wall segments. (All above information shall be included in the Foundation Report)
• SD and GP together will determine the minimum spacing between adjacent anchors. • When extended creep tests are required, SD and GP together will determine the number of extended creep tests, test load schedule, and the test locations.	

Contractor will determine the vertical ground anchor bonded length and installation methods to meet the axial load test requirements.

* The performance test locations will be selected by the Caltrans field engineer.

Investigations

The geotechnical investigation should adequately define the subsurface conditions for design purposes and be consistent with the standards of practice identified in the Caltrans Geotechnical Manual. The extent of the exploration, field testing, and laboratory testing must give a reasonable degree of confidence in the property measured. At a minimum, the following items need be identified during the subsurface investigation which may affect the design and construction of the anchored system:

- Groundwater elevation.
- Cohesionless soils which may be susceptible to liquefaction and caving.
- Highly compressible materials such as high plasticity clays and organic soils, which are susceptible to long-term (creep) deformation.
- Obstructions, boulders, and hard rock layers which adversely affect anchor hole drilling and grouting.

Corrosion Testing Evaluation

Soil and/or water samples should be collected during the subsurface investigation to determine the corrosion potential at the project site. The corrosion evaluation will be based on Caltrans Corrosion Guidelines.

Vertical Ground Anchor Minimum Spacing

The minimum spacing of vertical ground anchors should be determined in the consideration of ground mass failure. The recommended minimum spacing between ground anchors should be ten times the diameter of the hole within the bonded length, or 5 feet minimum. Group effects of closely spaced anchors reduce the load carrying capacity of individual ground anchors. The recommended minimum spacing ensures that group effects between adjacent ground anchors are minimized and that anchor intersection due to drilling deviations is avoided. If smaller spacing than the minimum is required to develop the required anchor design force, consideration may be given to staggering anchors or installing anchors with a battered angle. SD and GP together should determine the minimum spacing between adjacent anchors.

Vertical Ground Anchor Minimum Unbonded Length

The minimum unbonded length for vertical ground anchors is 15 feet for strand tendons and 10 feet for bar tendons. Longer unbonded lengths may be required to ensure the bonded zone starts behind the critical potential failure surface. In general, the unbonded length is extended a minimum distance of 5 feet behind the critical potential failure surface. When determining the unbonded length, considerations also should be given to ensure the anchor bonded zone will not have significate impacts on the adjacent foundation elements.

Vertical Ground Anchor Load Testing and Lock-Off Load

All vertical ground anchors shall be load tested in the field to verify the required design loads can be achieved without excessive deformation. There are three types of load testing: performance testing, proof testing, and extended creep testing. They are discussed below.

Performance and Proof Testing

Performance tests involve incremental loading and unloading of a vertical ground anchor. Performance testing is performed on selected production vertical ground anchors. GP shall specify the minimum number of performance testing for each bridge footing and wall segment in the foundation report. The frequency of performance testing shall be at least 10%, but not less than 2, of the total vertical ground anchors per bridge footing; and shall be at least 5%, but not less than 3, of the total vertical ground anchors per retaining wall. The performance test locations will be selected by the Caltrans field engineer. The proof test involves a single load cycle. Proof testing is performed on remaining vertical ground anchors not selected for performance testing.

The performance and proof testing load schedules are listed in the project's Special Provisions. Examples of the load test schedules are shown in Table A1 of Appendix A. For both the performance and proof testing, vertical ground anchors are tested to 100% of the factored test load (FTL). Table 1 below describes how the FTL is determined.

Table 1: Determination of Factored Test Loads

Structure Type	Factored Test Load (FTL)
Bridge Foundations-regular	FTL= $\text{greater of } \frac{FDL}{\varphi} \text{ or } \frac{1.05T_s}{\varphi}$
Bridge Foundations-vertical ground anchor is a failure-critical member of a bridge in Extreme Event Limit State	FTL= $\text{greater of } \frac{1.05FDL}{\varphi} \text{ or } \frac{1.05T_s}{\varphi}$
Caltrans Type 7 Retaining Walls	T_p = greater of 1.33T_d or 1.25T_o

FDL= Factored design load, by SD.
T_s= Seismic design load, by SD.
Φ = Pullout resistance factor, use Φ = 0.7; for seismic design load (e.g., T_s), use Φ =1.0
T_p = Anchor factored test load for Caltrans Type 7 retaining wall, by SD.
T_d = Anchor design load for Caltrans Type 7 retaining wall, by SD.
T_o = Anchor lock-off load for Caltrans Type 7 retaining wall, by SD.

Extended Creep Testing

An extended creep test is a long duration test (approximately 8 hours) that is used to evaluate creep deformations of anchors. The extended creep test load hold times are much longer than the extended load hold times in the performance or proof tests. These tests are required for anchors installed in cohesive soil having a plasticity index greater than 20 or liquid limit greater than 50. For these ground conditions, GP should request extended creep testing in the Construction Considerations Section of the foundation report. When extended creep tests are required, SD and GP together will determine the number of extended creep tests, testing load schedule, and the test locations. Generally, a minimum of two ground anchors should be subjected to extended creep testing per bridge footing; and a minimum of three for retaining walls. Refer to Table A-2 of Appendix A for an example of extended creep testing load schedule (from FHWA IF-99-015).

Lock-Off Load

Depending on the lock-off load, vertical ground anchors can be classified as active or passive ground anchors. For bridge foundations, passive vertical ground anchors are usually prestressed to a lock-off load equal to 10% of the factored design load (FDL); and active vertical ground anchors are prestressed to a load equal to or over 100% of factored design load. For retaining wall foundations, only active vertical ground anchors are used. SD will specify the lock-off loads (LL for bridge foundation, T_o for Caltrans Type 7 retaining wall) on the project plan sheets.

Reporting

For vertical ground anchors to be used in a bridge foundation, report in accordance with the *Foundation Reports for Bridges* module. For vertical ground anchors to be used in a retaining wall, report in accordance with the *Foundation Reports for Earth Retaining Systems* module.

Appendix A: Example Test Schedules

Table A1: Performance and Proof Load Test Schedules (from 2018 SSP)

Performance Test		Proof Test	
Load Increment	Hold Time (minutes)	Load Increment	Hold Time (minutes)
AL	Until stable	AL	Until stable
0.20T	1-2	0.20T	1-2
AL	Until stable	0.40T	1-2
0.20T	1-2	0.60T	1-2
0.40T	1-2	0.80T	1-2
AL	Until stable	1.00T*	10 or 60
0.20T	1-2	AL	Until stable
0.40T	1-2	-	-
0.60T	1-2	-	-
AL	Until stable	-	-
0.20T	1-2	-	-
0.40T	1-2	-	-
0.60T	1-2	-	-
0.80T	1-2	-	-
AL	Until stable	-	-
0.20T	1-2	-	-
0.40T	1-2	-	-
0.60T	1-2	-	-
0.80T	1-2	-	-
1.00T*	10 or 60	-	-
AL	Until stable	-	-

AL=alignment load, 0.10T
T=factored test load
*Maximum test load

Table A2: Example of Extended Creep Load Test Schedule (from FHWA IF-99-015)

Loading Cycle	Maximum Cycle Load	Total Observation Period (min.)	Movements Measured at Following Times (min.)
AL	Until stable	-	-
1	0.25FDL	10	1, 2, 3, 4, 5, 6, 10
2	0.50FDL	30	1, 2, 3, 4, 5, 6, 10, 15, 20, 25, 30
3	0.75FDL	30	1, 2, 3, 4, 5, 6, 10, 15, 20, 25, 30
4	1.00FDL	45	1, 2, 3, 4, 5, 6, 10, 15, 20, 25, 30, 45
5	1.20FDL	60	1, 2, 3, 4, 5, 6, 10, 15, 20, 25, 30, 45, 60
6	1.33FDL*	300	1, 2, 3, 4, 5, 6, 10, 15, 20, 25, 30, 45, 60, 300
AL	Until stable	-	-

AL=alignment load, 0.10FDL
FDL=factored design load
*Maximum test load