ROCK ANCHORS

**From Highgate STP 0297(8)(Re-advertised)

xx. DESCRIPTION. This work shall consist of furnishing, installing, and testing rock anchors at the locations indicated in the Plans.

xx. GENERAL. Rock anchors consist of steel bars inserted in boreholes drilled into the rock. Rock anchors shall be post tensioned, have an anchorage or bonded anchor length, and may require two-stage grouting. The borehole annulus is to be filled with cement grout in order to provide encapsulation and corrosion protection for the steel bar. The rock anchors will be finished as detailed in the Plans and specified herein.

xx. APPLICABLE STANDARDS AND SPECIFICATIONS. The most recent versions of the cited standards and specifications shall be used to govern the quality of work and materials.

ASTM A 36	Standard Specification for Structural Steel
ASTM A 123	Zinc (Hot-Dip Galvanized) Coatings for Iron and Steel Products
ASTM A 153	Zinc Coating (Hot-Dip Galvanized) on Iron and Steel Hardware
ASTM A 563	Standard Specification for Carbon and Alloy Steel Nuts
ASTM A 722	Uncoated High Strength Steel Bar for Prestressing Concrete
ASTM A 789	Standard Practice for Repair of Damaged Hot Dip Galvanized Coatings
ASTM C 109	Compressive Strength of Hydraulic Cement Mortars
ASTM F 436	Standard Specification for Hardened Steel Washers

Post Tensioning Institute Recommendations for Prestressed Rock and Soil Anchors, 2006.

xx. MATERIALS.

(a) Rock Anchors and Accessories. All rock anchors shall consist, at a minimum, of Grade 150, galvanized, continuous thread bar with a nominal diameter of 1 inch. The bars shall consist of pre-stressing steel conforming to ASTM A 722.

Rock anchor steel shall be handled and stored in such a manner as to avoid damage or corrosion. Damage to the rock anchor steel as a result of abrasion, cuts, nicks, welds, and weld splatter will be cause for rejection by the Engineer.

Rock anchor steel shall be protected from dirt, rust and deleterious substances. All exposed parts of the rock anchor, bearing plate, and spherical nuts shall be galvanized in accordance with ASTM A 123/ASTM A 153. Bar ends, where cut, shall be painted with a cold galvanizing compound following installation.

Bearing plates shall be of steel conforming to the requirements of ASTM A 36 and be as detailed in the Plans.

Beveled or spherical washers shall be steel or malleable iron. Flat washers shall be quenched and tempered steel and shall conform to the requirements of ASTM F 436.

Anchor nuts shall be the manufacturer's standard heavy-duty hexagon head type designed for use with the rock anchors and shall be galvanized in accordance with ASTM A 153. Anchor nuts shall develop an ultimate strength not less than 100 percent of the guaranteed ultimate strength (GUTS) of the bar and conform to ASTM A 436.

Centralizers shall be made from plastic such as Schedule 40 PVC or class 200 PVC pipe, and shall support the bar so a ½ inch thick minimum cover of grout is maintained over the bar. Centralizers shall allow grout to flow freely around the bar. Centralizers shall be installed 3 feet from each end and at maximum 7 foot intervals between ends.

Couplings shall be Grade 150 steel, galvanized, and designed to equal the guaranteed ultimate strength of the bars.

(b) Cement. All Portland cement used to make grout shall, at a minimum, comply with the requirements of ASTM C 150, Type II or III. Chemical additives shall not be used without prior approval of the Engineer.

(c) Mixing Water. The water used for mixing shall be potable and free from substances which might be deleterious or corrosive to concrete or steel, and shall be furnished by the Contractor. The Contractor, if requested by the Engineer, shall submit reports of tests made by a competent laboratory on samples of the water which the Contractor proposes to use or is using.

xx. SUBMITTALS.

(a) Qualifications. Not less than two weeks prior to beginning any rock anchoring, the Contractor shall provide qualifications of Contractor's personnel in writing to the Engineer. The supervisors and drill operators shall have a minimum of two years of demonstrated experience in the installation of rock anchors.

(b) Work Plan. Not less than two weeks prior to beginning rock anchoring, the Contractor shall submit a detailed work plan for the rock anchors. The plan shall include:

(1) The proposed rope access methods and safety plan.

(2) Details of rock anchor type, couplings, face plate and nut, and method of installation for grout tubes and centralizers.

(3) Calibration certificates for equipment to be used for rock anchor installation and testing.

(4) Manufacturer's certificates/mill sheets for rock anchors and associated hardware.

(5) Proposed method of installation for rock anchors, including grout mixes, and drilling method.

Work shall not begin until the submittals have been approved in writing by the Engineer.

(c) Field Reports. The Contractor shall submit a field report on a daily basis to the Engineer. The field report shall include records of the location, length, and number of rock anchors installed, performance tests completed, and any difficulties encountered while drilling or installing the rock anchors.

xx. CONSTRUCTION REQUIREMENTS.

(a) General. Work shall proceed according to the approved Work Plan and schedule submitted by the Contractor prior to the beginning of work.

(b) Drilling. The orientation of the drill hole shall be as shown on the Plans. The anchors shall be installed within 5 degrees of the specified angle.

The Contractor shall flush the drill hole of all drill cuttings and debris with compressed air prior to the installation of the rock anchor. 5

Holes drilled for rock anchoring in which anchor installation is considered by the Engineer to be unacceptable or impractical shall be re-drilled at the Contractor's expense.

The Contractor's drillers shall keep and provide a borehole log for each borehole drilled for rock anchors. The log shall include, but not be limited to, the following:

(1) Hole location, diameter, length, and angle from horizontal.

(2) Date/time of drilling, drilling equipment used, encountered subsurface conditions (groundwater, joints, voids, soil/weak rock, etc.), and name of driller.

The Contractor shall submit the logs to the Engineer on a daily basis.

(c) Grout Mixing. Cement grout shall consist of a maximum of five gallons of clean potable water per sack consisting of 94 pounds of Type II or III Portland cement. The grout shall be mixed for a minimum of five minutes in a paddle-type grout mixer and passed through a #4 size sieve before being used. Grout may be pumped or fed by gravity into the tremmie pipe or grout tube. Grout containing lumps or that has been in the grout mixer for more than 30 minutes shall not be used. No chemical additives shall be used unless approved in writing by the Engineer. The use of epoxy grout will not be permitted.

The Contractor shall flush the drill hole of all drill cuttings and debris with compressed air prior to grout installation.

(d) Anchor Installation. Anchor installation shall be completed in three stages consisting of establishing an anchorage for the bar, tensioning, and grout encapsulation of the tensioned anchor. Depending on the type of anchorage, two-stage grouting may be required. Design Load (DL) for the anchor shall be as specified on the Plans.

Following acceptable testing of the bond zone and locking-off the anchor at the design load (DL), the second stage encapsulation grouting shall be completed. The quantity of grout required to fill each hole will vary and is highly dependent upon geologic conditions.

Grouting of holes shall be performed by placing grout through a tremmie tube installed at the bottom of the open hole. The tremmie tube may be withdrawn as grouting proceeds, however grout shall be maintained over the end of the tremmie tube at all times.

First stage grouting, if used to establish the anchorage, will be completed to establish a bond length sufficient to resist the DL or as directed by the Engineer. For the first stage grouting, the anchor bar should be inserted in the hole and the grout placed through a tremmie tube to the level desired. Observe the grout level for five minutes. If grout level drops more than one inch, re-fill the hole to the level desired. The use of a grout sock will be permitted to limit grout loss.

Second stage grouting will be completed when the first stage anchor grout has attained at least 50 percent of its specified 28-day compressive strength and can resist the DL or the anchorage has been tested. The Contractor shall re-flush the hole of all debris with compressed air prior to second stage grouting. Following the placement of the grout through a tremmie tube and filling the "birds beak" annulus between the anchor and the hole with hand-packed grout, the bearing plate, washer, and nut will be installed and the anchor loaded to 1.10 times the DL. The nut shall be tightened with a wrench to lock off the anchor at the DL and the jack shall be removed.

After acceptance of the anchor by the Engineer, the end of the bar shall be cut to its final length as directed by the Engineer. Cutting of the bars with torches will not be permitted. Anchor ends, where cut, shall be painted with a cold galvanizing compound following installation.

(e) Anchor Grout Testing. The strength of the grout for the anchors shall be tested at least every 10 anchors. The testing shall be performed by VTrans. Acceptable grout shall have a minimum compressive strength of 4500 psi at 28 days.

(f) Rock Anchor Testing.

(1) For each different method of anchor installation, two successful performance tests shall be performed to verify the Contractor's installation methods, anchor pullout capacity, and design assumptions. The tests shall be performed prior to installation of production anchors at locations within the limits of work specified by the Engineer. Anchor testing shall not be performed until the anchor grout has attained at least 50 percent of its specified 28-day compressive strength. All test data shall be recorded and submitted to the Engineer in writing.

(2) Fifteen percent of production soil anchors will be proof tested. Anchor testing shall not be performed until the anchor grout has attained at least 50 percent of its specified 28-day compressive strength. All test data shall be recorded and submitted to the Engineer in writing.

(3) Testing equipment shall include two dial gauges, a dial gauge support, jack and pressure gauge, a load cell, and a reaction frame. A minimum of two dial gauges capable of measuring to 0.001 inch shall be available at the site to measure the anchor movement. The dial gauges shall have a minimum travel sufficient to allow the test to be performed without re-setting the dial gauge. The dial gauges shall be aligned within 5 degrees of the axis of the dowel and shall be supported independent of the jacking set-up and the soil. A hydraulic jack, pressure gauge, and pump shall be used to apply and measure the test load. Test set-up shall be as approved by the Engineer.

(4) The jack and pressure gauge shall be calibrated by an independent test laboratory as a unit. The pressure gauge shall be graduated in 100 psi increments or less. The jack shall be capable of tensioning anchor bars to 80 percent of the guaranteed ultimate tensile strength of the bars within the rated pressure capacity of the pumping units, unless approved otherwise by the Engineer.

(5) The jack shall be independently supported and centered over the anchor so that the anchor does not carry the weight of the jack. The stressing equipment shall be placed over the anchor in such a manner that the jack, bearing plates, and stressing anchorage are in alignment. The jack shall be positioned at the beginning of the test such that unloading and repositioning of the jack will not be required during the test. The Contractor will be required to provide a bearing pad for each test. The bearing pad shall be constructed to a size and thickness that will prevent failure of the pad or movement of the test jack or bearing plate.

(6) Details of the testing arrangement, including the method of distributing test load pressures to the excavation surface or reaction frame, test anchor bar size, grouted hole diameter, and reaction plate dimensioning shall be developed by the Contractor and submitted to the Engineer for approval. The test anchors shall be constructed using the same equipment, methods, and hole diameter as planned for the production anchors. Changes in the drilling or installation method may require additional performance testing as determined by the Engineer; such testing shall be provided at no additional cost to VTrans.

(7) Performance test anchors shall have both bonded and unbonded lengths. Prior to testing, only the bonded length of the test anchor shall be grouted. The unbonded length of the test anchor shall be at least 2 feet unless approved otherwise by the Engineer. The bond length shall be determined by the Engineer based on the design pullout load for the anchors and the design bond stress indicated in the WMSS design documents. The test load (TL) shall not exceed 1.33 times the design load (DL) and shall not exceed 80 percent of the guaranteed ultimate tensile strength for the bar. The DL for the anchors shall be taken as the pre-tensioning load as specified on the Plans.

(8) Performance test anchors shall be cyclically and incrementally loaded and unloaded in accordance with the schedule shown below. The load shall be decreased to the alignment load (AL) after each cycle maximum, and the movement of each successive alignment load step shall be recorded. At each load increment, the total movement of the pulling head shall be recorded to the nearest 0.001 inch with respect to an independent fixed reference point. The load shall be held at each increment just long enough to obtain the movement reading but no longer than 1 minute. Movement readings at the maximum test load (1.33 DL) shall be taken at 1, 2, 3, 4, 5, 6 and 10 minutes to measure creep rate. If the total creep movement between 1 and 10 minutes exceeds 0.040 inch, the test load shall be maintained for an additional 50 minutes. Total movements shall then be recorded at 20, 30, 40, 50 and 60 minutes from the start of the test load hold time.

Cycle	Increment	1	2	3	4	5	6
1	AL	0.25DL					
2	AL	0.25 DL	0.5 DL				
3	AL	0.25 DL	0.5 DL	0.75 DL			
4	AL	0.25 DL	0.5 DL	0.75 DL	1.0 DL		
5	AL	0.25 DL	0.5 DL	0.75 DL	1.0 DL	1.25 DL	
6	AL	0.25 DL	0.5 DL	0.75 DL	1.0 DL	1.25 DL	1.33 DL

(9) Proof test anchors shall be incrementally loaded in accordance with the schedule shown below. At each load increment, the total movement of the pulling head shall be recorded to the nearest 0.001 inch with respect to an independent fixed reference point. Movement readings at the maximum test load (1.33 DL) shall be taken at 1, 2, 3, 4, 5, 6 and 10 minutes to measure creep rate. If the total creep movement between 1 and 10 minutes exceeds 0.040 inch, the test load shall be maintained for an additional 50 minutes. Total movements shall then be recorded at 20, 30, 40, 50 and 60 minutes from the start of the test load hold time.

Load	Movement Measurement	
AL		
0.25 DL	X	
0.50 DL	X	
0.75 DL	X	
1.00 DL	X	
1.25 DL	X	
1.33 DL	X	Test Load start
		X Test Load at final hold

(g) Anchor Test Acceptance. A test dowel shall be considered acceptable when:

(1) A creep rate is observed to be less than 0.04 inches per log cycle of time between the 1 and 10 minute reading or, if exceeded, less than 0.080 inches per log cycle of time between the 6 and 60 minute readings and the rate is linear or decreasing at the end of the creep test load hold period.

(2) The total movement at the test load exceeds 80 percent of the theoretical elongation of the unbonded length (plus jack length), and is less than 100 percent of the theoretical elongation of the unbonded length (plus jack length) plus 50 percent of the bonded length.

(3) A pullout failure does not occur during testing. Pullout failure is defined as the load at which attempts to increase the test load simply result in continued pullout movement of the test anchor.

(h) The Contractor shall evaluate the results of each performance test and submit a test results summary to the Engineer. Anchor installation methods that do not satisfy the anchor testing requirements shall be considered inadequate. The Contractor shall propose alternative methods and install replacement performance test anchors at no additional cost to VTrans.

xx. METHOD OF MEASUREMENT. The quantity of Special Provision (Rock Anchor Testing) to be measured for payment will be the number of each rock anchor test performed in the complete and accepted work.

The quantity of Special Provision (Rock Anchor) to be measured for payment will be the number of meters (linear feet) of anchors installed in the complete and accepted work, as obtained from the Contractor's daily field reports approved by the Engineer.

xx. BASIS FOR PAYMENT. The accepted quantity of Special Provision (Rock Anchor Testing) will be paid for at the Contract unit price per each. Payment will be full compensation for performance testing the rock anchors, proof testing production anchors, obtaining acceptable results for all tests, and for furnishing all labor, tools, equipment, and incidentals necessary to complete the work.

The accepted quantity of Special Provision (Rock Anchor) will be paid for at the Contract unit price per meter (linear foot). Payment will be full compensation for furnishing, drilling, installing, and grouting the rock anchor and for furnishing all labor, tools, equipment, and incidentals to complete the work.

Payment for preparing and making required submittals will not be made separately, but will considered incidental to the work under this Section.

Payment will be made under:

Pay Item		Pay Unit
900.620	Special Provision (Rock Anchor Testing)	Each
900.640	Special Provision (Rock Anchor)	Meter (Linear Foot)