ITEM 203.17150117 - PERMANENT ROCK ANCHORS, FURNISHED, INSTALLED AND ACCEPTED
ITEM 203.17150217 - PERFORMANCE TESTS FOR PERMANENT ROCK ANCHORS
ITEM 203.17150317 - CREEP TESTS FOR PERMANENT ROCK ANCHORS

DESCRIPTION

A. General. This work shall consist of designing, furnishing, installing and testing both test and permanent rock anchors at the locations indicated in the contract documents. The anchors shall be designed to be restressable. Use the anchor loads, orientations, stressing lengths and rock bond strengths shown in the contract documents.

The Contractor or subcontractor performing the work shall submit his design and methods of construction to the Deputy Chief Engineer Technical Services (DCETS) for approval. The design shall be accomplished by a Professional Engineer licensed to practice in New York State. The DCETS will require 20 working days to approve the submission after receipt of all pertinent information. No further work shall begin prior to approval by the DCETS.

The Contractor or subcontractor performing the work described in this specification shall submit proof of the following:

1. Two projects on which he has installed rock anchors in the past two years.
2. The foreman for this work having supervised the installation of rock anchors on at least two projects in the past two years.

B. Definitions. The following definitions shall apply:

**Contractor.** The contractor or subcontractor performing the work described in this specification.

**Rock Anchor.** A system used to transfer tensile loads from a structure to rock. A rock anchor includes all prestressing steel (tendon), the anchorage, grout, coatings, bondbreaker, couplers, and encapsulation.

**Tendon.** The steel used to transfer load from the anchorage to rock.

**Anchorage.** That portion of the rock anchor, including bearing plate, nuts and washers, that is used to transfer load from the structure to a tendon. Temporary anchorages at the vault walls will be used to test the permanent rock anchors. The temporary anchorages will remain in place. Permanent anchorages as detailed in the contract documents will be used to permanently offload the existing eyebars.

**Bond Breaker.** A grease filled, smooth sleeve placed over the stressing length of the encapsulation that allows elongation of the stressing length during stressing and remains unbonded after lockoff.

**Bond Length.** That portion of the rock anchor which is bonded to the rock and transfers the tensile force from the tendon to the rock.

**Tendon Bond Length.** The length of the tendon which is bonded to the grout. This is usually, but not necessarily, the same as the Bond Length.
Stressing Length. That portion of the tendon which is not bonded to grout.

Encapsulation. A grout filled, corrugated tube protecting the prestressing steel against corrosion.

Total Movement. The total elongation of the rock anchor under load, measured at the anchor head.

Residual Movement. The permanent set of the rock anchor resulting from stressing and releasing the rock anchor.

Trumpet. A steel pipe or tube, integrally attached to the bearing plate, that surrounds the tendon in the vicinity of the structure.

Creep Rate. The magnitude of total movement measured during a load hold per log cycle of time.

Centralizer. A device used to center the rock anchor in the hole to assure minimum grout cover over the rock anchor.

GUTS. The Guaranteed Ultimate Tensile Strength of the tendon.

MATERIALS

A. Tendons. The tendon shall consist of clean, straight, rust-free continuously threaded "Uncoated High-Strength Steel Bar for Prestressing Concrete" - ASTM A722. The tendons shall be fusion bonded epoxy coated in accordance with ASTM A775. The tendons shall be of such size that the design load does not exceed 60 percent of the GUTS of the tendons. At no time shall a test or temporary load on any tendon exceed 80 percent of the GUTS of the tendon.

B. Couplers. Couplers for tendons shall be capable of developing 100 percent of the GUTS of the tendon.

C. Bond Breaker. Grease filled, bond breaker sleeves shall allow the stressing length to elongate elastically with minimal friction during testing and stressing.

D. Anchorage. The anchorage shall be capable of developing 95 percent of the GUTS of the tendon and shall be set so that only axial loads are applied.

E. Grease. A grease compounded to provide corrosion inhibiting and lubricating properties shall completely cover the steel in the stressing length. Acceptable greases for the stressing length shall be:

1. Exxon Rust Ban 326
2. Chevron Polyurea EP Grease, #2 Grade
3. Viscon Visconorust PT-1
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or equal, as approved by the Director of the Geotechnical Engineering Bureau.

Greases other than those above shall be submitted to an independent laboratory for analysis at the Contractor's expense. The test results shall be submitted to the Geotechnical Engineering Bureau for approval or rejection and shall not exceed the maximum allowable quantity of the substances shown on the following table:

<table>
<thead>
<tr>
<th>Substance</th>
<th>Maximum Allowable Quantity - ppm</th>
<th>Test Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chlorides</td>
<td>10</td>
<td>ASTM D512</td>
</tr>
<tr>
<td>Nitrates</td>
<td>10</td>
<td>ASTM D992</td>
</tr>
<tr>
<td>Sulfides</td>
<td>10</td>
<td>APHA - &quot;Test Methods: Sulfides in Water&quot;</td>
</tr>
</tbody>
</table>

F. **Encapsulation** A grout filled, corrugated, polyethylene tube conforming to ASTM D1248 or ASTM D3350, to provide corrosion protection for the bond length and the stressing length.

G. **Centralizers**

1. Centralizers shall consist of plastic, steel or any material not detrimental to the tendon. Wood shall not be used.

2. Centralizers shall permit free flow of grout.

H. **Grout.** The grout shall consist of materials meeting the following specification requirements:

<table>
<thead>
<tr>
<th>Material</th>
<th>Subsection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Portland Cement, Type 1, 2, or 3</td>
<td>701-01</td>
</tr>
<tr>
<td>Grout Sand</td>
<td>703-04</td>
</tr>
<tr>
<td>Water</td>
<td>712-01</td>
</tr>
</tbody>
</table>

Epoxy resin will not be allowed as a substitute for cement grout.

I. **Additives.** Chemical additives to control bleeding or retard set, as approved by the Engineer, may be used with the grout. Expansive additives shall not be used. Additives, if used, shall be mixed in accordance with the manufacturer's recommendations.

J. **Trumpet.** The trumpet shall be integral with the bearing plate. The trumpet shall consist of an epoxy coated steel pipe or tube conforming to the requirements of ASTM A53 for pipe or ASTM A500 for tubing.
The trumpet shall have an inside diameter equal to or larger than the hole in the bearing plate, and shall be long enough to accommodate movements of the structure during loading and testing. A seal to retain grease within the trumpet shall be provided between the trumpet and the stressing length corrosion protection. A description of the seal shall be submitted to the Engineer for approval.

CONSTRUCTION DETAILS

A. Shop Drawings. Shop drawings shall be submitted to the Engineer for written approval at least 30 working days prior to commencement of the work. Shop drawings shall conform to the size and type requirements of §718-01 Prestressed Concrete Units (Structural), under Drawings, Working Drawings, A. Size and Type. No work shall begin prior to receipt of the approval.

The shop drawings shall include, but not be limited to:

1. A rock anchor schedule giving:
   a. Rock anchor number
   b. Design load for each rock anchor
   c. Type and size of tendon
   d. Total tendon length
   e. Bond length, and tendon bond length if different from bond length
   f. Stressing length
   g. Hole size

2. A drawing of the rock anchor and corrosion protection including:
   a. Centralizers and their location
   b. Stressing and bond length corrosion protection
   c. Bond breaker
   d. Anchorage and trumpet

3. Construction methods that will be used to ensure that the anchors align with the jacking beams as shown in the contract documents.

B. Completion Report. The Contractor shall submit a report to the Engineer within 20 working days after completion of the rock anchor work. The report shall contain:

1. As-built drawings showing the locations of the rock anchors, total tendon lengths, stressing lengths and bond lengths
2. Prestressing steel manufacturer's mill test reports for the tendons
3. Grouting records indicating the cement type, quantity injected and grout pressures
4. Rock anchor test results and graphs
C. **Rock Anchor Design.** The Contractor shall be responsible for determining the rock anchor type, size and bond length necessary to develop adequate load capacity to satisfy rock anchor testing acceptance criteria for the design loads shown in the contract documents.

D. **Hole Progression.** The holes for the rock anchors shall be drilled. Subsidence or physical damage to existing site conditions caused by such operations shall be cause for immediate cessation of operations and repair to the satisfaction of the State. The Contractor shall immediately revise his operations to prevent reoccurrence of such damage. Any and all costs incurred due to this subsidence or physical damage shall be borne by the Contractor. If the hole will not stand open, casing shall be installed as required to maintain a clean and open hole. The hole shall extend a minimum of 2 feet beyond the tendon length. The holes shall be located in elevation as shown in the contract documents. The holes shall be progressed to the inclination and alignment as specified in the contract documents. The holes shall be thoroughly cleaned of all dust, rock chips, grease or other material which may affect bond prior to inserting the tendon.

E. **Water Tightness Test.** A water tightness test will be required for all rock anchors if grout is injected at a pressure of less than 50 psi. If artesian or flowing water is encountered in the drilled hole, pressure shall be maintained on the grout until the grout has reached initial set. The water tightness test shall be performed by filling the entire hole in the rock with water and subjecting it to a pressure of 5 psi as measured at the top of the hole. If the stressing length portion of hole is in fractured rock, a packer or casing shall be used to allow the bond length to be pressure-tested. If the leakage rate from the hole, over a ten minute period, exceeds 0.001 gallons of water per inch of diameter per foot of length per minute, the hole shall be grouted, redrilled and retested. Should the subsequent water tightness test fail, the entire process shall be repeated until results are attained which are within leakage allowances.

The Contractor may eliminate the requirement for water tightness tests in rock by using pressure grouting techniques. Pressure grouting requires that the drill hole be sealed and that the grout be injected until a 50 psi grout pressure, measured at the top of the hole, can be maintained on the grout for 5 minutes without further grout injection.

F. **Centralizers.** In the bond length, centralizers and their installed locations shall be subject to approval by the Engineer. Centralizers shall be provided at a maximum of 10 feet center to center spacing throughout the tendon length so that not less than 0.5 inches of grout cover along the tendon length is achieved. A centralizer shall be provided at the bottom end of the tendon. Sag of the tendon shall be taken into account when selecting centralizer diameter and spacing.

G. **Tendon Installation.** The bond length of the tendon shall be degreased prior to installation by using Acetone, MEK, or MIBK. No residue shall be left on the tendon. Other substances may be used subject to approval by the Engineer.

The tendon shall be inserted in the casing or hole without difficulty. If the tendon cannot be completely inserted, the Contractor shall remove the tendon and clean or redrill the hole to permit insertion. Partially inserted tendons shall not be driven or otherwise forced into the hole.
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Tendons shall not be subject to sharp bends. Care shall be taken to prevent damage to the tendon's corrosion protection and centralizers during handling and installation.

H. Grouting. The grouting equipment shall be capable of continuous mixing and shall produce grout free of lumps. The grout pump shall be equipped with a grout pressure gage capable of measuring the highest working pressures attained plus 50 psi.

The annular space between the rock anchor and the drilled hole up to the level of the trumpet and between the tendon and encapsulation shall be filled with grout. In order to prevent air voids in the grouting operation, the hole shall be filled with grout progressively from bottom to top. Grouting of the stressing length shall be done at low pressure. Any temporary casing shall be withdrawn during the grouting operation. The trumpet shall not bear on the top of the stressing length grout column during testing, to ensure that load applied to the rock anchor during testing is not transferred to the anchorage via the grout column.

I. Corrosion Protection. Encapsulation shall be required to provide double-corrosion protection for the tendons. The tendons shall be encapsulated in a grout-filled corrugated tube using internal centralizers. The inside diameter of the encapsulation shall be at least 0.4 inches larger than the nominal diameter of the tendon. The tendon may be grouted inside the encapsulation either before or after inserting the tendon into the drill hole.

The rock anchor shall be centered in the trumpet so that there is no contact between the two. The corrosion protection surrounding the stressing length of the tendon shall extend up beyond the bottom seal of the trumpet but shall not contact the bearing plate or anchor head during stressing and testing.

After installation, testing and acceptance of each rock anchor, the trumpet shall be filled with grout or corrosion inhibiting grease.

TESTING
Perform the following tests as specified in the Special Notes in the contract documents:

Performance Tests. These tests are used to determine residual movements.

Creep Tests. These tests are performed to determine long term deformation behavior.

Proof Tests. These tests are used to verify load capacity.

Lift-Off Readings. Lift-off readings shall be taken on all rock anchors after the load has been transferred to the anchorage, but prior to removing the jack.

Lift-Off Tests. Lift-off tests shall be used to verify the anchor loads on the jacking beam.

Copies of all test results and graphs shall be transmitted to the Director, Geotechnical Engineering Bureau as each test is completed.
Jacks shall be calibrated by an independent testing laboratory within 14 days prior to the start of testing. Jacks shall have ram travel at least equal to the theoretical elastic elongation of the stressing length plus the bond length at the maximum test load, and be sufficient to accommodate wall movements. A pressure gauge shall be used with each jack. Gauges shall be calibrated with a single jack and shall not be used with any other jack. All gauges shall be accurate enough to read 100 psi changes in pressure. For performance and creep tests, the jack used shall have two calibrated gauges; a master gauge and backup gauge. The pump shall be capable of applying each load increment in less than 60 seconds.

A load cell, which has been calibrated by an independent testing laboratory within 14 days prior to the start of testing, shall be used to measure the small changes in load during the load hold portion of the performance and creep tests. There will be no substitute for the load cell on testing of the performance and creep tests. Load cells are not required for proof tests. The Contractor shall provide the Engineer with the calibration curve for the load cell prior to testing.

For the performance and creep tests, the master gauge and backup gauge shall be connected to the same pressure hose between the pump and jack and be used to measure the applied loads. If the load measured by the master gauge and backup gauge differ by more than 10 percent, the jack, master gauge and backup gauge shall be recalibrated as a unit at no expense to the State.

At the completion of the test the rock anchor load shall be adjusted to the lock-off load and transferred to the anchorage. Unless otherwise specified in the contract documents, the lock-off load shall be 100 percent of the design load (1.0 P).

The alignment load necessary to maintain position of the stressing and testing equipment shall not exceed 0.05 P. The movement of the rock anchor tendon at each load increment shall be recorded to the nearest 0.001 inch relative to an independent, fixed reference point.

**A. Performance Tests.** Performance tests shall be performed by incrementally loading and unloading the rock anchor in accordance with the schedule below. Residual movements shall be taken at the alignment load for each cycle. Total movement measurements shall be taken at the highest load in each cycle.

<table>
<thead>
<tr>
<th>Cycle</th>
<th>Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>AL</td>
</tr>
<tr>
<td></td>
<td>0.25 P</td>
</tr>
<tr>
<td>2</td>
<td>AL</td>
</tr>
<tr>
<td></td>
<td>0.25 P</td>
</tr>
<tr>
<td></td>
<td>0.50 P</td>
</tr>
<tr>
<td>3</td>
<td>AL</td>
</tr>
<tr>
<td></td>
<td>0.25 P</td>
</tr>
<tr>
<td></td>
<td>0.50 P</td>
</tr>
</tbody>
</table>
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0.75 P

4 AL
0.25 P
0.50 P
0.75 P
1.00 P

5 AL
0.25 P
0.50 P
0.75 P
1.00 P
1.20 P

6 AL
0.25 P
0.50 P
0.75 P
1.00 P
1.20 P
1.33 P

Adjust to lock-off of 1.0 P

P = Design load for the rock anchor
AL = Alignment load

The load shall be held at each increment just long enough to obtain the total movement reading. Except for the residual movement at AL, no movement readings need to be taken during unloading of the rock anchor.

The test load of 1.33 P shall be held constant for 10 minutes. The load hold time shall start when the pump begins to load the anchor from the 1.20 P load to the test load. A load cell shall be used to monitor the constant load. Total movements with respect to an independent fixed reference point shall be recorded at 1 minute, 2, 3, 4, 5, 6, and 10 minutes. If the total movement between 1 minute and 10 minutes exceeds 0.040 inches, the test load shall be held for an additional 50 minutes. Total movements shall be recorded at 15, 20, 25, 30, 45 and 60 minutes.

The Contractor shall plot the tendon movement versus load for each load increment. He shall also plot the creep movement for the load hold as a function of the logarithm of time.

B. Creep Tests. The creep test shall be made by incrementally loading and unloading the tendon in accordance with the schedule given below. At the highest load in each cycle the load
shall be held constant in accordance with the observation periods below. A load cell shall be used to monitor the constant load.

<table>
<thead>
<tr>
<th>Cycle</th>
<th>Load</th>
<th>Observation Period (Min.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>AL 0.25 P</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>AL 0.25 P, 0.50 P</td>
<td>30</td>
</tr>
<tr>
<td>3</td>
<td>AL 0.25 P, 0.50 P, 0.75 P</td>
<td>30</td>
</tr>
<tr>
<td>4</td>
<td>AL 0.25 P, 0.50 P, 0.75 P, 1.00 P</td>
<td>45</td>
</tr>
<tr>
<td>5</td>
<td>AL 0.25 P, 0.50 P, 0.75 P, 1.00 P, 1.20 P</td>
<td>60</td>
</tr>
<tr>
<td>6</td>
<td>AL 0.25 P, 0.50 P, 0.75 P, 1.00 P, 1.20 P, 1.33 P</td>
<td>300</td>
</tr>
</tbody>
</table>

Residual movement measurements shall be taken at the alignment load for each cycle. Total movement readings shall be taken at the highest load in each cycle.

The times for reading the total movement during an observation period shall be 1 minute, 2, 3, 4, 5, 6, 10, 15, 20, 25, 30, 45, 60, 75, 90, 100, 120, 150, 180, 210, 240, 270, and 300 minutes.
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The observation period shall begin when the pump starts to load the rock anchor from the next lower increment.

The Contractor shall plot the tendon movement and the residual movement measured in a creep test as described for the performance test. The Contractor shall also plot the creep movement for each load hold as a function of the logarithm of time.

If the creep rates are not acceptable as defined under Acceptance Criteria, the Contractor shall modify his installation method and perform creep tests until two successive acceptable creep tests on two different rock anchors have been performed.

C. Proof Tests. The proof tests shall be performed by loading the rock anchor in accordance with the following schedule:

<table>
<thead>
<tr>
<th>Load</th>
<th>AL</th>
<th>0.25 P</th>
<th>0.50 P</th>
<th>0.75 P</th>
<th>1.00 P</th>
<th>1.20 P</th>
<th>1.33 P</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Adjust to lock-off load of 1.0 P</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The load shall be held at each increment just long enough to obtain a total movement reading, but not more than 1 minute.

The test load of 1.33 P shall be held for at least 10 minutes. The load hold time shall start when the pump begins to load the rock anchor from 1.20 P to the test load. Total movements shall be recorded at 1, 2, 3, 4, 5, 6, and 10 minutes. If the movement between the 1 and the 10 minute readings is 0.040 inches or more, the test load shall be maintained for an additional 50 minutes and the movement measured. The additional movement shall be recorded at 15 minutes, 20, 25, 30, 45, and 60 minutes.

The Contractor shall plot the tendon movement versus load for each load increment. He shall also plot the creep movement for the load hold as a function of the logarithm of time.

D. Lift-Off Readings. Lift-off readings shall be taken and recorded directly after testing on all rock anchors. The load required to relieve the load from the rock anchor head shall be measured and recorded. If the lift-off load is not within 5% of the lock-off load the anchorage shall be reset and another lift-off reading taken.
E. Lift-Off Tests. Lift-off tests shall be performed on all permanent rock anchors. The Contractor shall leave an adequate length of tendon protruding over the jacking beam to permit jacking.

Lift-off tests shall be performed at least 30 days, but no more than 45 days after the rock anchor has been set to lock-off load. The results of all lift-off tests shall be recorded.

If the lift-off load is not within 10% of the lock-off load, the anchorage shall be reset and another lift-off test performed according to the requirements in this specification.

F. Acceptance Criteria

1. General
   a. For all rock anchors:
      • All rock anchors and components shall be free of detrimental corrosion.
      • Lift-off readings shall show a load within 5 percent of the specified lock-off load.
      • Lift-off tests shall show a load within 10 percent of the specified lock-off load.
      • The total movement at the maximum test load shall exceed 80 percent of the theoretical elastic elongation of the unbonded length, from the alignment load to the test load.
   b. For performance or proof tested rock anchors with a 10 minute load hold, the rock anchor shall also resist the maximum test load with a creep rate that does not exceed 0.040 inches between the 1 and 10 minute readings.
   c. For performance or proof tested rock anchors with a 60 minute load hold, the rock anchor shall also resist the maximum test load with a creep rate that does not exceed 0.080 inches per log cycle of time.
   d. For creep tested rock anchors, the rock anchor shall also resist the maximum test load with a creep rate that does not exceed 0.080 inches per log cycle of time.

For rock anchors that the Engineer finds unacceptable, the Contractor shall submit a written proposal containing a suggested course of action. The action to be taken will be subject to written approval by the Engineer.

METHOD OF MEASUREMENT

A. Permanent Rock Anchors, Furnished, Installed and Accepted. This work will be measured as the number of rock anchors furnished, installed and accepted.

B. Performance Tests for Permanent Rock Anchors. This work will be measured as the number of performance tests performed.
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C. Creep Tests for Permanent Rock Anchors. This work will be measured as the number of creep tests performed.

BASIS OF PAYMENT

A. Permanent Rock Anchors, Furnished, Installed and Accepted. The unit price bid shall include the cost of furnishing all labor, equipment, and material required to satisfactorily complete the work. The cost for proof tests, lift-off readings, and lift-off tests shall also be included.

B. Performance Tests for Permanent Rock Anchors. The unit price bid shall include the cost of furnishing all labor, equipment and material required to satisfactorily complete the tests.

C. Creep Tests for Permanent Rock Anchors. The unit price bid shall include the cost of furnishing all labor, equipment and material required to satisfactorily complete the tests.

Payment will be made under:

<table>
<thead>
<tr>
<th>Item No.</th>
<th>Item</th>
<th>Pay Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>203.17150117</td>
<td>Permanent Rock Anchors, Furnished, Installed and Accepted</td>
<td>Each</td>
</tr>
<tr>
<td>203.17150217</td>
<td>Performance Tests for Permanent Rock Anchors</td>
<td>Each</td>
</tr>
<tr>
<td>203.17150317</td>
<td>Creep Tests for Permanent Rock Anchors</td>
<td>Each</td>
</tr>
</tbody>
</table>