Special Specification 4184
Prestressed Rock Anchors

1. DESCRIPTION

Install post-tensioned permanent prestressed rock anchors in place with permanent casing and grouting as required in accordance with the plans and these specifications. Ensure the rock anchors provide the load carrying capacities that will develop the load as required on the plans and the approved working drawings and in accordance with the testing requirements of this specification.

The Contractor may also propose to use proprietary systems, which do not conform to all provisions of this specification, if the concept is approved by the Engineer. The system selected must provide the magnitude and distribution of design prestressing force and minimum ultimate strength required by the plans without exceeding allowable temporary stresses. If Contractor cannot provide the load carrying capacities in accordance with the plans, additional anchors will be installed. The Contractor has the option to change the anchoring procedure with the approval of the Engineer as long as the required load carrying capacity is achieved. Ensure design procedures, coefficients, and allowable stresses are in accordance with the latest Standard AASHTO Specifications for Highway Bridges.

2. MATERIALS

Provide materials required for use under this Item conforming to Table 1:

Table 1

Materials

Material	Conform to Item
Structural Steel	Item 441 and 442
Prestressing Steel	Item 426
Hydraulic Cement Concrete	Item 421

Provide prestressing steel conforming to:

- seven wire strand conforming to ASTM Designation A416, including Supplementary Requirement S1, and should be weldless, low-relaxation grade; or
- wire or strand with greater ultimate strength but otherwise produced and tested in accordance with ASTM designation A416, and the requirements of this specification, are permitted provided the physical properties as outlined in the applicable specification are shown on the shop drawings and provided they have no properties which make them less satisfactory than the specified material.

Each rock anchor tendon is a group of strands with a common end anchorage used to apply a stressing force to the structural member. Provide coated (unbonded) tendons except for the portion which is established as the anchorage length. Coat the tendons a minimum of the unbonded length shown on the plans. Ensure the anchorage length is bare and completely free of grease or other contaminants. Provide the minimum acceptable anchorage lengths shown on the plans.

Provide end anchorages that are capable of developing 95% of the guaranteed ultimate tensile strength of the prestressing steel when tested in the unbonded state. Provide ductile iron wedge plates (i.e., anchor head) and three-part wedges. Use material for coating unbonded tendons that is non-volatile, low friction mineral oil base grease, with a rust preventing additive having a relatively uniform viscosity in a temperature

range of 20 F to 120 F. Provide a protective sheathing around the tendon throughout the coated stressing length consisting of 0.04 in. minimum thickness polypropylene, polyethylene, or polyvinyl chloride tubing capable of maintaining the tendon tightly bundled and containing the lubricant.

Provide centralizers and spacers that are fabricated from plastic, steel or other approved material which is nondetrimental to the prestressing steel. Wood is prohibited. Use centralizers that support the tendon in the drill hole and position the tendon to maintain a minimum of 1/2 in. of grout cover. Furnish centralizers and spacers that permit grout to flow freely around the tendon and up the drill hole. Provide a permanent anchor cap to seal the anchor head in grease within 7 days of stressing.

Provide grout for rock anchors that is a neat cement or sand cement mixture, with a minimum 7-day compressive strength of 3500 psi. Determine grout strengths by testing 2 in. cubes in accordance with Test Method TEX-442-A or 3 in. diameter by 6 in. high cylinders in accordance with Test Method TEX-418-A. Determine the grout strength by testing the initial grout batch. Additional testing is necessary if the grout mixture is modified or if required by the Engineer. If allowed by the Engineer, test results from previous projects using an identical grout mix may be accepted.

Provide grout tubes with an inside diameter that is adequate to enable the cement grout to be pumped readily and without blockage to the bottom of the drill hole; and strong enough to withstand the expected grout pressure.

Provide permanent casing that is fabricated with seamless steel and flush square-cut threaded joints, in accordance with API Specification 5CT, Grade N80. Provide Guide Sleeves in accordance with ASTM A53, Type S seamless, Grade A or B.

Identify the tendons by heat number, or reel number in the case of seven-wire strand, and tag them for identification. Identify anchorage assemblies in a like manner. At the request of the Engineer, furnish specimens for test purposes in accordance with Test Method TEX-710-I. Provide mill test reports for tendons used in permanent anchors.

Test complete tendons for compliance with the requirements of this specification at no expense to the Department and certify the results in writing. In addition, furnish for testing, one specimen of each size of prestressing tendon with end fittings attached at each end for ultimate strength tests only.

Provide a specimen 5 ft. in clear length, measured between the ends of the fittings. If the results of the test indicate the necessity of check tests, furnish additional specimens at no cost to the Department. For prestressing systems previously tested and approved on Department projects, complete tendon samples need not be furnished provided there is no change in the material, design, or details previously approved. For the shop drawings or prestressing details, identify the project on which approval was obtained, otherwise sampling will be necessary. For prefabricated rock anchor assemblies, notify the Engineer at least 10 days before installing the end fittings or heading the wires so that sampling and testing may be arranged.

3. PACKAGING, STORING, AND HANDLING

Protect the prestressing steel against physical damage and corrosion from the time of manufacture to grouting or encasing in concrete.

Rust on prestressing steel, which can be removed by light rubbing, is acceptable. Streaks or spots, which may remain after rust removal, are acceptable if no pitting is present. Tight mill scale is acceptable but remove loose mill scale.

Protect prefabricated rock anchor assemblies from moisture by taping, wrapping, or by other acceptable means.

Before inserting the tendon into the drilled hole, examine the corrosion protection elements for damage. Repair encapsulation in accordance with the tendon supplier's recommendations.

4. EQUIPMENT

Furnish suitable equipment to drill the holes to the diameter, depth, and line as specified in this specification or on the approved working drawings.

Furnish suitable hydraulic jacks for stressing the tendons. Equip jacks with load cell and Bourdon pressure gauge that is graduated to read directly to 1% of the total load applied; and, calibrated to measure accurately the stress induced in the steel.

Provide jacks with a stroke of adequate length so that the stressing, including temporary overstress, can be done in one movement. Equip them with proper ports or windows for adequate visual examination and measurement of tendon movement. Ensure they are also capable of slow release of stress to allow relaxation from overstress to the proper seating force. Furnish jack pumps that are capable of applying each load increment in less than 60 sec. and capable of maintaining the hydraulic pressure within 50 psi. Furnish a hydraulic jack with ram travel that is not less than the theoretical elastic elongation of the total anchor tendon length at the maximum Test Load.

Provide a dial indicator, piano wire, and mirror system to measure tendon elongation. Furnish a dial indicator that is capable of measuring displacement to the nearest 0.001 in., with enough stroke to measure displacement during the entire duration of anchor test without being reset.

Furnish a grout mixer and pump of enough capacity to properly place grout in the quantities required.

5. WORKING DRAWINGS

Submit working drawings (i.e. shop drawings) for the rock anchors a minimum of 1 mo. before the installation of the rock anchors. Provide the details containing the necessary information for construction including the following.

5.1. **Prestressing Details.** On the drawings, show details of type, size, number of units per rock anchor, rock anchor diameter, inclination, forces applied per anchor, corrosion protection, end anchorage systems, grouting and venting ports, drilling and grouting procedure, acceptable elongation, stressing procedure, temporary overstress, and other information necessary to properly complete the work.

On these details, show the method of support for the rock anchors to ensure that the proper location in the center of the hole can be maintained.

5.2. **Anchor Layout.** Provide drawings showing the layout of the anchors, required load, and proposed length of soldier pile relative to the proposed drilled shafts.

6. CONSTRUCTION

6.1. **General.** Before stressing the anchors, furnish certified copies of load calibration curves on the jacks and gauge systems to be used in the work. Calibrate the hydraulic pump, Bourdon pressure gage, load cell, jack, and ram as a unit no more than 6 mo. before starting work. Recalibrate stressing systems when directed or at least every 6 mo.

6.2. **Drilling.** Drill the hole within +/- 3° from the line specified on the approved working drawings.

Instead of water-tightness testing, pre-grout and re-drill anchor holes before insertion of the anchor tendon in the drill hole.

6.3. **Grouting.** Clear the hole of debris before placing the tendon. Insert the tendon in the hole and use tendon centralizers to ensure that the tendon is centered in the hole with a maximum 1 in. of sag between the supports. Provide a grout tube that allows placing the grout from the bottom of the hole. Before beginning to pump the grout, check the grout tubes to ensure they are clear.

Grout rock anchors immediately after placing the tendon in the drill hole. Pump the grout from the bottom of the drill hole toward the top, continuously under pressure, until the grout is within approximately 1 ft. of the top of the drill hole. Grout the hole full length in one stage with clearance provided between the grout and the tendon anchorage.

If the grout level in the hole cannot be maintained, withdraw the tendon and re-drill the hole after at least 24 hr. have passed. Complete the re-drilling before the point in time when the grout compressive strength equals the compressive strength of the surrounding rock mass.

Record the data shown in Table 2 concerning the grouting:

Table 2
Grouting Data to Record

Water-cement ratio	Volume of Grout
Types of Additives	Type of Mixer
Types of Cement	

6.4. **Corrosion Protection.** Provide Class II "Single Corrosion Protection," in which the post-tensioned strand is encapsulated in cement grout. This detail will be submitted to the Engineer for review and approval.

6.5. **Post-Tensioning.** Do not begin post-tensioning until the concrete in the associated structural members has reached the design strength specified.

Provide suitable means for measuring the movement of the anchor head to the nearest 0.001 in.

Indicate on the prestressing details, a sequence of post-tensioning that prevents overstressing the structural member.

Ensure the prestressing details submitted reflect the following general tensioning procedure modified as required for each particular installation, unless otherwise required by the plans.

- Tendons in the sequence designated in the Prestressing Details.
- Perform initial tensioning to take the slack out of the tendons at 10% of the anchor Design Load (DL) unless otherwise shown on the approved Prestressing Details.
- After the initial tensioning, set up an independent reference to measure the anchor movement.

  Use the dial indicator to measure anchor movement. Provide a separate piano wire and mirror to back-check the dial indicator readings.

  Elongation Acceptance Criteria. Ensure the movement measured at the Test Load (TL) is within the following limits:

  - The minimum apparent elastic movement (δ_e) of the tendon at the TL, is not less than the magnitude of movement that is computed based on the elastic elongation of 80% of the unbonded length plus the jack length.
  - The maximum apparent elastic movement (δ_e) of the tendon at the TL, is less than the magnitude of movement that is computed based on the elastic elongation of 100% of the unbonded length and jack length plus 50% of the bonded length.

  If the movement measured is not within the above specified limits, the anchor will be rejected. In that case, install a replacement anchor at no cost to the Department.

■ Performance test the 4 planned rock anchors in accordance with the following procedures

The performance test will be made by incrementally loading and unloading the anchor in accordance with the following schedule. All loads except the maximum test load need only be held long enough to obtain the movement reading, but no longer than 1 minute.

Performance Test Schedule

Load	Total Movement at load cycle Maximum	Residual Movement at AL after cycle Maximum	Apparent Elastic Movement at load cycle Maximum
	δ_t	δ_r	δ_e
AL			
0.25 DL	δ_{t1}		$\delta_{e1} = \delta_{t1} - \delta_{r1}$
AL		δ_{r1}	
0.25 DL			
0.50 DL	δ_{t2}		$\delta_{e2} = \delta_{t2} - \delta_{r2}$
AL		δ_{r2}	
0.25 DL			
0.50 DL			
0.75 DL	δ_{t3}		$\delta_{e3} = \delta_{t3} - \delta_{r3}$
AL		δ_{r3}	
0.25 DL			
0.50 DL			
0.75 DL			
1.00 DL	δ_{t4}		$\delta_{e4} = \delta_{t4} - \delta_{r4}$
AL		δ_{r4}	
0.25 DL			
0.50 DL			
0.75 DL			
1.00 DL			
1.20 DL	δ_{t5}		$\delta_{e5} = \delta_{t5} - \delta_{r5}$
AL		δ_{r5}	
0.25 DL			
0.50 DL			
0.75 DL			
1.00 DL			
1.20 DL			
1.33 DL= TL	δ_{t6} Test Load (zero reading for Creep Test)		
	δ_{tn} Final Load Hold reading		$\delta_{e6} = \delta_{t6} - \delta_{r6}$
AL Adjust to Lock-Off load = 241 kips		δ_{r6}	

AL = Alignment Load = 24.1 kips for a 9-strand tendon
with a guaranteed ultimate tensile strength (GUTS) of 58.6 kips per strand
DL = Design Load = 241 kips for a 9 strand tendon
TL = Test Load = 1.33 DL = 321 kips for a 9 strand tendon
LO = Lock-Off Load = 241 kips for a 9 strand tendon

Creep Test Acceptance Criteria. The maximum test load will be held for 10 min. The anchor movement, with respect to a fixed reference, will be recorded at 1, 2, 3, 4, 5, 6 and 10 min. If the total creep movement between 1 and 10 min. readings exceeds 0.04 in., extend the test load for an additional 50 min. If the test is extended, the movement must be recorded at 20, 30, 40, 50, and 60 min. The creep test should begin after reaching the 1.33 DL maximum test load. During load hold periods, maintain a constant load that is within +/- 50 psi of the target jack pressure. Repumping back to the Test Load is permissible to compensate for small movement. The load will always be required to be returned to the specified Test Load before taking the movement reading at a specified interval. If the movement exceeds 0.08 in. during the 50 min. hold (i.e., from 10 to 60 minute creep test readings), the anchor will be rejected and considered a failure.

- If the rock anchor fails the acceptance criteria at a certain pre-assigned location, the Contractor has the option to offset the anchor location at a distance of 3 times the sleeve diameter. The Contractor will submit shop drawings for additional locations for the approval by the Engineer.
- After testing has been completed successfully and satisfies the elongation and creep test acceptance criteria cited above, transfer the load to the tendon anchorage at the specified lock-off (LO) load.
- After transferring the load to the tendon anchorage, and before removing the jack, complete a lift-off test to confirm the magnitude of tendon lock-off (LO) load. Complete the lift-off test load by re-applying load to the wedge plate without unseating the wedges. Lift-Off is measured by observing the pressure gauge to the point at which there is a marked reduction in the rate of gain of jack pressure. Ensure that the lift off load is within 10% of the lock-off load. If the lift-off load deviates from the lock-off load by more than 10%, then readjust the tendon load, reset the stressing wedges, and repeat the lift-off test.
- Perform final post-grouting of the anchor plate area to fill any voids present within the annular space between the anchor tendon and the guide sleeve under the sub-bearing plate.

Rock anchors will be considered acceptable if the anchor movement in any testing does not exceed the limits specified in Article 6.5. The anchor movements must also fall within the limits stated in Article 6.E.3.

Anchors which fail to attain the maximum test load required, as stated above, may be incorporated into the drilled shaft anchorage system at a load capacity equal to one half their failure loads. The failure load is the load indicated by the pressure gauge 10 min. after failure occurs. Then install additional anchors to replace or supplement the failed anchor. The Contractor is responsible for the entire cost of installing any required additional anchors or changes in the original anchor design.

7. MEASUREMENT

This Item will be measured by each rock anchor that conforms with the acceptance criteria and is completed in accordance with the plans and specifications.

8. PAYMENT

The work performed and materials furnished, in accordance with this Item and measured as provided under "Measurement," will be paid for at the unit price bid for "Prestressed Rock Anchors." This price is full compensation for work performed, materials furnished, labor, tools, equipment, and incidentals. Prestressed ground anchor tests are subsidiary to this item.