

6-17 PERMANENT GROUND ANCHORS

6-17.1 Description

This Work consists of constructing permanent ground anchors.

6-17.2 Materials

Materials required, including materials for permanent ground anchors, shall be as specified in the Special Provisions.

6-17.3 Construction Requirements

The Contractor shall select the ground anchor type and the installation method, and determine the bond length and anchor diameter. The Contractor shall install ground anchors that will develop the load indicated in the Plans and verified by tests specified in Sections 6-17.3(8)A, 6-17.3(8)B, and 6-17.3(8)C.

6-17.3(1) Definitions

Anchor Devices: The anchor head wedges or nuts that grip the prestressing steel.

Bearing Plate: The steel plate that evenly distributes the ground anchor force to the Structure.

Bond Length: The length of the ground anchor that is bonded to the ground and transmits the tensile force to the soil or rock.

Ground Anchor: A system, referred to as a tieback or as an anchor, used to transfer tensile loads to soil or rock. A ground anchor includes all prestressing steel, anchorage devices, grout, coatings, sheathings and couplers if used.

Maintaining Consistency of Load: Maintaining the test load within 5-percent of the specified value.

Minimum Guaranteed Ultimate Tensile Strength (MUTS): The minimum guaranteed breaking load of the prestressing steel as defined by the specified standard.

Tendon Bond Length: The length of the tendon that is bonded to the anchor grout.

Tendon Unbonded Length: The length of the tendon that is not bonded to the anchor grout.

Total Anchor Length: The unbonded length plus the tendon bond length.

6-17.3(2) Contractor Experience Requirements

The Contractor or Subcontractor performing this Work shall have installed permanent ground anchors for a minimum of 3-years. Prior to the beginning of construction, the Contractor shall submit a list containing at least 5 projects on which the Contractor has installed permanent ground anchors. A brief description of each project and a reference shall be included for each project listed. As a minimum, the reference shall include an individual's name and current phone number.

The Contractor shall assign an engineer to supervise the Work with at least 3-years of experience in the design and construction of permanently anchored Structures. The Contractor shall not use consultants or manufacturer's representatives in order to meet the requirements of this section. Drill operators and on-site supervisors shall have a minimum of 1-year experience installing permanent ground anchors.

Contractors or Subcontractors that are specifically prequalified in Class 36 Work will be considered to have met the above experience requirements.

The Contractor shall allow up to 15-calendar days for the Engineer's review of the qualifications and staff as noted above. Work shall not be started on any anchored wall system nor materials ordered until approval of the Contractor's qualifications are given.

6-17.3(3) Submittals

The Contractor shall submit Working Drawings and structural design calculations in accordance with Section 6-01.9 for the ground anchor system or systems intended for use.

The Contractor shall submit a detailed description of the construction procedure proposed for use to the Engineer for approval.

The Contractor shall submit a ground anchor schedule giving:

1. Ground anchor number
2. Ground anchor design load
3. Type and size of tendon
4. Minimum total bond length
5. Minimum anchor length
6. Minimum tendon bond length
7. Minimum unbonded length

The Contractor shall submit Working Drawings of the ground anchor tendon and the corrosion protection system. Include details of the following:

1. Spacers and their location
2. Centralizers and their location
3. Unbonded length corrosion protection system, including the permanent rubber seal between the trumpet and the tendon unbonded length corrosion protection.
4. Bond length corrosion protection system
5. Anchorage and trumpet
6. Anchorage corrosion protection system
7. Anchors using non-restressable anchorage devices

The Contractor shall submit shop plans as specified in Section 6-03.3(7) for all structural steel, including the permanent ground anchors to the Engineer for review and approval.

The Contractor shall submit the grout mix designs and the procedures for placing the grout to the Engineer for approval. The Contractor shall also submit the methods and materials used in filling the annulus over the unbonded length of the anchor.

The Contractor shall submit 5 copies of detailed Working Drawings in accordance with Section 6-01.9 for the method proposed to be followed for the permanent ground anchor testing to the Engineer for approval prior to the tests. This shall include all necessary drawings and details to clearly describe the method proposed.

The Contractor shall submit to the Engineer calibration data for each load cell, test jack, pressure gauge and master pressure gauge to be used. The calibration tests shall have been performed by an independent testing Laboratory and tests shall have been performed within 60-calendar days of the date submitted. The Engineer shall approve or reject the calibration data after receipt of the data. Testing shall not commence until the Engineer has approved the load cell, jack, pressure gauge and master pressure gauge calibrations.

Work shall not begin until the Engineer has approved the appropriate submittals in writing.

6-17.3(4) Preconstruction Conference

A permanent ground anchor preconstruction conference shall be held at least 5-working days prior to the Contractor beginning any permanent ground anchor Work at the site to discuss construction procedures, personnel, and equipment to be used. The list of materials specified on the Record of Materials Form (ROM) for this item of Work will also be discussed. Those attending shall include:

1. (representing the Contractor) The superintendent, on site supervisors, and all foremen in charge of drilling the ground anchor hole, placing the permanent ground anchor and grout, and tensioning and testing the permanent ground anchor.
2. (representing the Contracting Agency) The Project Engineer, key inspection personnel, and representatives from the WSDOT Construction Office and Materials Laboratory Geotechnical Services Branch.

If the Contractor's key personnel change, or if the Contractor proposes a significant revision of the approved permanent ground anchor installation plan, an additional conference shall be held before any additional permanent ground anchor operations are performed.

6-17.3(5) Tendon Fabrication

The tendons can be either shop or field fabricated. The tendon shall be fabricated as shown in the approved shop plans.

The Contractor shall select the type of tendon to be used. The tendon shall be sized so the design load does not exceed 60-percent of the minimum guaranteed ultimate tensile strength of the tendon. In addition, the tendon shall be sized so the maximum test load does not exceed 80-percent of the minimum guaranteed ultimate tensile strength of the tendon.

The Contractor shall be responsible for determining the bond length and tendon bond length necessary to develop the design load indicated in the Plans in accordance with Sections 6-17.3(8)A, 6-17.3(8)B, and 6-17.3(8)C. The minimum bond length shall be 10-feet in rock and 15-feet in soil.

When the Plans require the tendon bond length to be encapsulated, the tendon bond length portion of the tendon shall be corrosion protected by encapsulating the tendon in a grout-filled PE or PVC tube as specified in Section 6-17.2 as supplemented in the Special Provisions. The tendons can be grouted inside the encapsulation prior to inserting the tendon in the drill hole or after the tendon has been placed in the drill hole. Expansive admixtures can be mixed with the encapsulation grout if the tendon is grouted inside the encapsulation while outside the drill hole. The tendon shall be centralized within the bond length encapsulation with a minimum of 0.20-inches of grout cover. Spacers shall be used along the tendon bond length of multi-element tendons to separate the elements of the tendon so the prestressing steel will bond to the encapsulation grout.

Centralizers shall be used to provide a minimum of 0.5-inches of grout cover over the tendon bond length encapsulation. Centralizers shall be securely attached to the encapsulation and the center-to-center spacing shall not exceed 10-feet. In addition, the upper centralizer shall be located a maximum of 5-feet from the top of the tendon bond length and the lower centralizer shall be located a maximum of 1-foot from the bottom of the tendon bond length.

The centralizer shall be able to support the tendon in the drill hole and position the tendon so a minimum of 0.5-inches of grout cover is provided and shall permit free flow of grout.

Centralizers are not required on encapsulated, pressure-injected ground anchor tendons if the ground anchor is installed in coarse grained soils (more than 50-percent of the soil larger than the number 200 sieve) using grouting pressures greater than 150-psi.

Centralizers are not required on encapsulated, hollow-stem-augered ground anchor tendons if the ground anchor is grouted through and the hole is maintained full of a stiff grout (8-inch slump or less) during extraction of the auger.

The minimum unbonded length of the tendon shall be the greater of 15-feet or that indicated in the Plans.

Corrosion protection of the unbonded length shall be provided by a sheath completely filled with corrosion inhibiting grease or grout. If grease is used under the sheath, provisions shall be made to prevent the grease from escaping at the ends of the sheath. The grease shall completely coat the tendon and fill the voids between the tendon and the sheath. The Working Drawings shall show how the Contractor will provide a transition between the tendon bond length and the unbonded tendon length corrosion protection.

If the sheath is not fabricated from a smooth tube, a separate bond breaker shall be provided. The bond breaker shall prevent the tendon from bonding to the anchor grout surrounding the tendon unbonded length.

The total anchor length shall not be less than that indicated in the Plans or the approved Working Drawings.

Anchorage devices shall be capable of developing 95-percent of the minimum guaranteed ultimate tensile strength of the prestressing steel tendon. The anchorage devices shall conform to the static strength requirements of Section 3.1 of the Post Tensioning Institute "Specification for Unbonded Single Strand Tendons, First Edition - 1993".

Non-restressable anchorage devices may be used except where indicated in the Plans.

Restressable anchorages shall be provided on those ground anchors that require reloading. The post-tensioning supplier shall provide a restressable anchorage compatible with the post-tensioning system provided.

The bearing plates shall be sized so the bending stresses in the plate do not exceed the yield strength of the steel when a load equal to 95-percent of the minimum guaranteed ultimate tensile strength of the tendon is applied, and the average bearing stress on the concrete does not exceed that recommended in Section 3.1.3 of the Post Tensioning Institute, "Specification For Unbonded Single Strand Tendons, First Edition - 1993".

The trumpet shall have an inside diameter equal to or larger than the hole in the bearing plate. The trumpet shall be long enough to accommodate movements of the Structure during testing and stressing. For strand tendons with encapsulation over the unbonded length, the trumpet shall be long enough to enable the tendon to make a transition from the diameter of the tendon in the unbonded length to the diameter of the tendon at the anchor head without damaging the encapsulation. Trumpets filled with corrosion-inhibiting grease shall have a permanent rubber seal, as approved by the Engineer, provided between the trumpet and the tendon unbonded length corrosion protection. Trumpets filled with grout shall have a temporary seal provided between the

trumpet and the tendon unbonded length corrosion protection or the trumpet shall overlap the tendon unbonded length corrosion protection.

6-17.3(6) Tendon Storage And Handling

Tendons shall be handled and stored in such a manner as to avoid damage or corrosion. Damage to the prestressing steel as a result of abrasions, cut, nicks, welds and weld splatter will be cause for rejection by the Engineer. The prestressing steel shall be protected if welding is to be performed in the vicinity. Grounding of welding leads to the prestressing steel is forbidden. Prestressing steel shall be protected from dirt, rust, and deleterious substances. A light coating of rust on the steel is acceptable. If heavy corrosion or pitting is noted, the Engineer will reject the affected tendons.

The Contractor shall use care in handling and storing the tendons at the site. Prior to inserting a tendon in the drill hole, the Contractor and the Engineer will examine the tendon for damage to the encapsulation and the sheathing. If, in the opinion of the Engineer, the encapsulation is damaged, the Contractor shall repair the encapsulation in accordance with the tendon supplier's recommendations and as approved by the Engineer. If, in the opinion of the Engineer, the smooth sheathing has been damaged, the Contractor shall repair it with ultra high molecular weight polyethylene (PE) tape. The tape shall be spiral wound around the tendon so as to completely seal the damaged area. The pitch of the spiral shall ensure a double thickness at all points.

6-17.3(7) Installing Permanent Ground Anchors

The Contractor shall select the drilling method, the grouting procedure, and the grouting pressure used for the installation of the ground anchor.

When caving conditions are encountered, no further drilling will be allowed until the Contractor selects a method to prevent ground movement. The Contractor may use a temporary casing. The Contractor's method to prevent ground movement shall be approved by the Engineer. The casings for the anchor holes, if used, shall be removed. The drill hole shall be located so the longitudinal axis of the drill hole and the longitudinal axis of the tendon are parallel. The ground anchor shall not be drilled in a location that requires the tendon to be bent in order to enable the bearing plate to be connected to the supported Structure. At the point of entry the ground anchor shall be installed within plus or minus 3-degrees of the inclination from horizontal shown in the Plans or the approved Working Drawings. The ground anchors shall not extend beyond the Right of Way limits.

The tendon shall be inserted into the drill hole to the desired depth. When the tendon cannot be completely inserted without difficulty, the Contractor shall remove the tendon from the drill hole and clean or redrill the hole to permit insertion. Partially inserted tendons shall not be driven or forced into the hole.

The Contractor shall use a grout conforming to Section 6-17.2 as supplemented in the Special Provisions.

The grout equipment shall produce a grout free of lumps and undispersed cement. A positive displacement grout pump shall be used. The pump shall be equipped with a pressure gauge near the discharge end to monitor grout pressures. The pressure gauge shall be capable of measuring pressures of at least 150-psi or twice the actual grout pressures used by the Contractor, whichever is greater. The grouting equipment shall be sized to enable the grout to be pumped in 1 continuous operation. The mixer shall be capable of continuously agitating the grout.

The grout shall be injected from the lowest point of the drill hole. The grout may be pumped through grout tubes, casing, or drill rods. The grout can be placed before or after insertion of the tendon. The quantity of the grout and the grout pressures shall be recorded. The grout pressures and grout takes shall be controlled to prevent excessive heave in soils or fracturing of rock formations.

After grouting, the tendon shall not be loaded for a minimum of 3-days.

No grout shall be placed above the top of the bond length during the time the bond length grout is placed. The grout at the top of the drill hole shall not contact the back of the Structure or the bottom of the trumpet. Except as otherwise noted, only nonstructural filler shall be placed above the bond length grout prior to testing and acceptance of the anchor. The Contractor may place structural grout above the bond length grout prior to testing and acceptance of the anchor subject to the following conditions:

1. The anchor unbonded length shall be increased by 8-feet minimum.
2. The grout in the unbonded zone shall not be placed by pressure grouting methods.

The corrosion protection surrounding the unbonded length of the tendon shall extend up beyond the bottom seal of the trumpet or 1-foot into the trumpet if no trumpet seal is provided. If the protection does not extend beyond the seal or sufficiently far enough into the trumpet, the Contractor shall extend the corrosion protection or lengthen the trumpet.

The corrosion protection surrounding the no load zone length of the tendon shown in the Plans shall not contact the bearing plate or the anchor head during testing and stressing. If the protection is too long, the Contractor shall trim the corrosion protection to prevent contact.

The bearing plate and anchor head shall be placed so the axis of the tendon and the drill hole are both perpendicular to the bearing plate within plus or minus 3-degrees and the axis of the tendon passes through the center of the bearing plate at the intersection of the trumpet and the bearing plate when fully seated with the alignment load.

The trumpet shall be completely filled with corrosion inhibiting grease or grout. Trumpet grease can be placed anytime during construction. Trumpet grout shall be placed after the ground anchor has been tested. The Contractor shall demonstrate to the Engineer that the procedure selected by the Contractor for placement of either grease or grout produces a completely filled trumpet.

All anchorages permanently exposed to the atmosphere shall be covered with a corrosion inhibiting grease-filled or grout-filled cover. The Contractor shall demonstrate to the Engineer that the procedures selected by the Contractor for placement of either grease or grout produces a completely filled cover. If the Plans require restressable anchorages, corrosion inhibiting grease shall be used to fill the anchorage cover and trumpet.

6-17.3(8) Testing And Stressing

Each ground anchor shall be tested. The test load shall be simultaneously applied to the entire tendon. Stressing of single elements of multi-element tendons will not be permitted. The Engineer will record test data.

The testing equipment shall consist of a dial gauge or vernier scale capable of measuring to 0.001-inches shall be used to measure the ground anchor movement. The movement-measuring device shall have a minimum travel equal to the theoretical elastic elongation of the total anchor length plus 1-inch. The dial gauge or vernier scale shall

be aligned so that its axis is within 5-degrees from the axis of the tieback. A hydraulic jack and pump shall be used to apply the test load. The jack and pressure gauge shall be calibrated by an independent testing Laboratory as a unit. Each load cell, test jack and pressure gauge, and master pressure gauge, shall be calibrated as specified in Section 6-17.3(3). Additionally, the Contractor shall not use load cells, test jacks and pressure gauges, and master pressure gauges, greater than 60-calendar days past their most recent calibration date, until such items are re-calibrated by an independent testing Laboratory.

The pressure gauge shall be graduated in increments of either 100-psi or 2-percent of the maximum test load, whichever is less. The pressure gauge will be used to measure the applied load. The pressure gauge shall be selected to place the maximum test load within the middle $\frac{2}{3}$ of the range of the gauge. The ram travel of the jack shall not be less than the theoretical elastic elongation of the total anchor length at the maximum test load plus 1-inch. The jack shall be independently supported and centered over the tendon so that the tendon does not carry the weight of the jack. The Contractor shall have a second calibrated jack pressure gauge at the site. Calibration data shall provide a specific reference to the jack and the pressure gauge.

The loads on the tiebacks during the performance and verification tests shall be monitored to verify consistency of load as defined in Section 6-17.3(1). Performance test loads, and verification test loads when specified in the Special Provisions, sustained for 5-minutes or less, and all proof test loads, shall be monitored by the jack pressure gauge alone. Performance test loads, and verification test loads when specified in the Special Provisions, sustained for longer than 5-minutes shall be monitored with the assistance of an electric or hydraulic load cell. The Contractor shall provide the load cell and a readout device. The load cell shall be mounted between the jack and the anchor plate. The load cell shall be selected to place the maximum test load within the middle $\frac{2}{3}$ of the range of the load cell. The stressing equipment shall be placed over the ground anchor tendon in such a manner that the jack, bearing plates, load cell and stressing anchorage are in alignment.

The permanent ground anchor load monitoring procedure for performance test loads, and verification test loads when specified in the Special Provisions, sustained for longer than 5-minutes shall be as follows:

1. For each increment of load, attainment of the load shall be initially established and confirmed by the reading taken from the jack gauge.
2. Once the permanent ground anchor load has been stabilized, based on the jack gauge reading, the load cell readout device shall immediately be read and recorded to establish the load cell reading to be used at this load. The load cell reading is intended only as a confirmation of a stable permanent ground anchor load, and shall not be taken as the actual load on the permanent ground anchor.
3. During the time period that the load on the permanent ground anchor is held at this load increment, the Contractor shall monitor the load cell reading. The Contractor shall adjust the jack pressure as necessary to maintain the initial load cell reading. Jack pressure adjustment for any other reason will not be allowed.
4. Permanent ground anchor elongation measurements shall be taken at each load increment as specified in Sections 6-17.3(8)A and 6-17.3(8)B.
5. Steps 1 through 4 shall be repeated at each increment of load, in accordance with the load sequence specified in Sections 6-17.3(8)A and 6-17.3(8)B.

6-17.3(8)A Verification Testing

Verification tests will be required only when specified in the Special Provisions.

6-17.3(8)B Performance Testing

Performance tests shall be done in accordance with the following procedures. Five-percent of the ground anchors or a minimum of 3 ground anchors, whichever is greater, shall be performance tested. The Engineer shall select the ground anchors to be performance tested. The first production anchor shall be performance tested.

The performance test shall be made by incrementally loading and unloading the ground anchor in accordance with the following schedule, consistent with the design method (Load Resistance Factor Design - LRFD or Load Factor Design - LFD) specified in the permanent ground anchor general notes in the Plans. The load shall be raised from one increment to another immediately after a deflection reading.

Performance Test Schedule

Load Resistance Factor Design Method (LRFD)	Load Factor Design Method (LFD)
Load	Load
AL	AL
0.25FDL	0.25DL
AL	AL
0.25FDL	0.25DL
0.50FDL	0.50DL
AL	AL
0.25FDL	0.25DL
0.50FDL	0.50DL
0.75FDL	0.75DL
AL	AL
0.25FDL	0.25DL
0.50FDL	0.50DL
0.75FDL	0.75DL
1.00FDL	1.00DL
AL	AL
Jack to lock-off load	0.25DL
	0.50DL
	0.75DL
	1.00DL
	1.25DL
	AL
	0.25DL
	0.50DL
	0.75DL
	1.00DL
	1.25DL
	1.33DL
	Jack to lock-off load

Where: AL - is the alignment load
 DL - is the design load
 FDL - is the factored design load.

The maximum test load in a performance test shall be held for 10-minutes. The load-hold period shall start as soon as the maximum test load is applied and the anchor movement, with respect to a fixed reference, shall be measured and recorded at 1-minute, 2, 3, 4, 5, 6, and 10-minutes. If the anchor movement between 1-minute and 10-minutes exceeds 0.04-inches, the maximum test load shall be held for an additional 50-minutes. If the load hold is extended, the anchor movement shall be recorded at 15-minutes, 20, 25, 30, 45, and 60-minutes. If an anchor fails in creep, retesting will not be allowed. All anchors not performance tested shall be proof tested.

6-17.3(8)C Proof Testing

Proof tests shall be performed by incrementally loading the ground anchor in accordance with the following schedule, consistent with the design method (Load Resistance Factor Design - LRFD or Load Factor Design - LFD) specified in the permanent ground anchor general notes in the Plans. The load shall be raised from one increment to another immediately after a deflection reading. The anchor movement shall be measured and recorded to the nearest 0.001-inches with respect to an independent fixed reference point at the alignment load and at each increment of load. The load shall be monitored with a pressure gauge. At load increments other than the maximum test load, the load shall be held just long enough to obtain the movement reading.

Proof Test Schedule	
Load Resistance Factor Design Method (LRFD)	Load Factor Design Method (LFD)
Load	Load
AL	AL
0.25FDL	0.25DL
0.50FDL	0.50DL
0.75FDL	0.75DL
1.00FDL	1.00DL
Jack to lock-off load	1.25DL
	1.33DL
	Jack to lock-off load

Where: AL - is the alignment load
 DL - is the design load
 FDL - is the factored design load

The maximum test load in a proof test shall be held for 10-minutes. The load-hold period shall start as soon as the maximum test load is applied and the anchor movement with respect to a fixed reference shall be measured and recorded at 1-minute, 2, 3, 4, 5, 6, and 10-minutes. If the anchor movement between 1-minute and 10-minutes exceeds 0.04-inches, the maximum test load shall be held of an additional 50-minutes. If the load hold is extended, the anchor movements shall be recorded at 15-minutes, 20, 25, 30, 45, and 60-minutes. If an anchor fails in creep, retesting will not be allowed.

6-17.3(9) Permanent Ground Anchor Acceptance Criteria

A performance or proof tested ground anchor with a 10-minute load hold is acceptable if the:

1. Ground anchor carries the maximum test load with less than 0.04-inches of movement between 1-minute and 10-minutes; and
2. Total movement at the maximum test load exceeds 80-percent of the theoretical elastic elongation of the tendon unbonded length.

A verification, performance or proof tested ground anchor with a 60-minute load hold is acceptable if the:

1. Ground anchor carries the maximum test load with a creep rate that does not exceed 0.08-inches/log cycle of time and is a linear or decreasing creep rate.
2. Total movement at the maximum test load exceeds 80-percent of the theoretical elastic elongation of the tendon unbonded length.

If the total movement of the ground anchors at the maximum test load does not exceed 80-percent of the theoretical elastic elongation of the tendon unbonded length, the Contractor shall replace the ground anchor at no additional cost to the Contracting Agency. Retesting of a ground anchor will not be allowed.

Ground anchors that have a creep rate greater than 0.08-inches/log cycle of time can be incorporated in the finished Work at a load equal to $\frac{1}{2}$ its failure load. The failure load is the load carried by the anchor after the load has been allowed to stabilize for 10-minutes.

When a ground anchor fails, the Contractor shall modify the design, the construction procedures, or both. These modifications may include, but are not limited to, installing replacement ground anchors, modifying the installation methods, increasing the bond length or changing the ground anchor type. Any modification that requires changes to the Structure shall have prior approval of the Engineer. Any modifications of design or construction procedures shall be at the Contractor's expense.

Upon completion of the test, the load shall be adjusted to the lock-off load indicated in the Plans and transferred to the anchorage device. The ground anchor may be completely unloaded prior to lock-off. After transferring the load and prior to removing the jack a lift-off reading shall be made. The lift-off reading shall be within 10-percent of the specified lock-off load.

If the load is not within 10-percent of the specified lock-off load, the anchorage shall be reset and another lift-off reading shall be made. This process shall be repeated until the desired lock-off load is obtained.

6-17.4 Measurement

Permanent ground anchors will be measured per each for each permanent ground anchor installed and accepted.

Permanent ground anchor performance tests will be measured per each for each anchor performance tested.

The permanent ground anchor verification testing program will not be measured but will be paid for on a lump sum basis.

6-17.5 Payment

Payment will be made in accordance with Section 1-04.1 for each of the following Bid items when they are included in the Proposal:

“Permanent Ground Anchor”, per each.

All costs in connection with furnishing and installing permanent ground anchors shall be included in the unit Contract price per each for “Permanent Ground Anchor”, including proof testing of the installed anchor as specified

“Permanent Ground Anchor Performance Test”, per each.

“Permanent Ground Anchor Verification Test”, lump sum.