STATE OF OHIO
DEPARTMENT OF TRANSPORTATION

SUPPLEMENTAL SPECIFICATION 866
GROUND ANCHORS

October 19, 2012

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866.01 Description. This work consists of designing grouted ground anchors to support the maximum test loads shown in the Plans, preparing shop drawings, installing, testing and stressing grouted ground anchors. Grouted ground anchors, also referred to as simply ground anchors, consist of tendons installed in grout-filled holes drilled in soil or rock. The tendons transfer tensile forces from an attached structure to the ground.

Select the drilling method, grouting method, grout mix, hole diameter, tendon steel, bond length, and unbonded length so that every ground anchor meets the specified acceptance criteria.

866.02 Definitions. For this specification, these terms are defined as follows:

Tendon and Tendon Steel. The tendon includes the steel bar or steel strands, the corrosion protection, the sheaths, centralizers, and spacers, but specifically excludes the grout and anchorage. The tendon steel consists of the steel bar or steel strands.

Bond length. The length of the tendon that is bonded to the grout and transfers the applied tensile force to the surrounding soil or rock.

Unbonded length. The length of the tendon that is not bonded to the grout and surrounding ground.

Anchor grout. Grout that is injected into the drill hole just before or just after the Contractor installs the tendon. The anchor grout within the bond length transfers the applied tensile force from the tendon to the surrounding soil or rock.

Anchorage. The combined system of the anchor head, bearing plate, and trumpet that transfers the force in the tendon to the ground surface or supported structure.
**Maximum test load.** The maximum load applied to the ground anchor during testing. The maximum test load is equal to the factored design load (FDL) for load and resistance factor design (LRFD) and to 1.33 times the design load (DL) for allowable stress design (ASD).

**Alignment load.** A nominal load applied to the ground anchor during testing to keep the testing equipment in the correct position.

**Lock-off load.** The tensile force or load in a ground anchor immediately after transferring the load from the jack to the anchorage after testing is complete.

866.03 **Materials**

A. **Tendons.** Furnish tendon steel for ground anchor tendons conforming to the following:

- Bar tendon.................................................. ASTM A722, Type II
- Strand tendon ............................................ ASTM A416 including S1

If required, furnish couplers for bar tendons from the same supplier as the bar tendon. Furnish couplers that develop 100 percent of the ultimate tensile strength of the bar tendon without evidence of failure.

Furnish steel products made in the United States according to 106.09.

B. **Centralizers and spacers.** Furnish centralizers and spacers made from plastic or steel. Centralizers must support the tendon in the hole and position it to provide at least 0.5 inch (13 mm) of grout cover over the encapsulation (or tendon steel if there is no encapsulation). Centralizers used inside the encapsulation must position the tendon steel to provide at least 0.2 inch (5 mm) of grout cover between the tendon steel and the inside surface of the encapsulation. Centralizers must permit grout to flow freely around the tendon and along the drill hole. Furnish spacers to separate multiple strands or bars within the bond length.

C. **Sheath, bond breaker, and encapsulation.** Furnish plastic tubing or pipe with the following properties:

1. Resistant to chemical attack from aggressive environments, grout, or corrosion inhibiting compounds.
2. Resistant to aging by ultraviolet light.
3. Fabricated from material that is not detrimental to the tendon.
4. Capable of withstanding abrasion, impact, and bending during handling and installation.
5. Allow the tendon to elongate during testing and stressing.

For the sheath, furnish plastic tubing or pipe, corrugated or smooth. A smooth sheath may also function as a bond breaker. Furnish a separate bond breaker with a corrugated sheath.

For the bond breaker, furnish smooth plastic tubing or pipe that allows the tendon to elongate with minimal friction during testing and stressing.
Furnish high density polyethylene corrugated pipe and end caps conforming to AASHTO M 252, Type C, for tendon bond length encapsulation.

D. **Corrosion inhibiting compound.** Furnish either grease, wax, or gel with corrosion inhibiting additives that conform with Section 4.6 of *Recommendations for Prestressed Rock and Soil Anchors* by the Post-Tensioning Institute (2004).

E. **Heat shrink sleeves and tape.** Furnish heat shrink sleeves and tape fabricated from radiation cross-linked polyolefin coated with an adhesive sealant.

F. **Wax tape.** Furnish petrolatum (wax) tape consisting of synthetic fabric saturated with a stable composition of petrolatum compound (wax) with inert fillers.

G. **Grout.** Furnish materials for grout conforming to the following:

- Portland cement .............................................. 701.02 or 701.04
- High early strength Portland cement .........................701.05

Furnish water conforming to 499.02. If using fine aggregate in the grout mix, furnish natural sand with 100 percent passing the No. 16 sieve (1.18 mm) and no more than 5 percent passing the No. 200 sieve (75 μm). Furnish water-reducing admixtures (Types A or F) conforming to 705.12. Do not use accelerating admixtures (Types C and E).

H. **Anchorages.** Furnish anchor heads conforming to either ASTM A36, ASTM A108 Grades 1040 or 1045, ASTM A536 Grade 80-55-06, or ASTM A576 Grade 1045.

For strand tendons, furnish three-part wedges conforming to ASTM A108 Grade 12L14, case hardened from 0.012 to 0.015 inches (0.30 to 0.38 mm) thick to Rockwell C 59 to 65. For strand tendons, furnish the anchor heads and wedges from the same supplier.

For bar tendons, furnish nuts conforming to one of the following: ASTM A29 Grade C1045, ASTM A108 Grades 1117 or 1144, ASTM A521 Class CF, or ASTM A536 Grade 100-70-03.

Furnish bearing plates conforming to either ASTM A36, ASTM A529, ASTM A536, ASTM A572, or ASTM A588.

Furnish trumpets fabricated from steel pipe conforming to ASTM A53 or steel tubing conforming to ASTM A500. Furnish trumpets with a minimum wall thickness of 0.20 inch (5 mm). Provide a watertight seal between the trumpet and bearing plate by welding the two together.

Furnish anchorage covers that completely cover the anchor head and provide a watertight joint between the cover and the bearing plate. Furnish anchorage covers with a minimum thickness of 0.20 inch (5 mm) and fabricated from either steel pipe conforming to ASTM A53, steel tubing conforming to ASTM A500, or steel conforming to either ASTM A36, ASTM A529, ASTM A572, or ASTM A588.

**866.04 Design.** The actual capacity of a ground anchor depends on many factors in addition to the soil or rock conditions at the site. Select the drilling method, grouting method, grout mix, hole diameter, tendon steel, bond length, and unbonded length appropriately for the
soil and rock conditions at the site, so that every ground anchor meets the specified acceptance criteria.

A. Design Requirements. Design the ground anchors according to the requirements listed below.

1. Tendon Steel. Select the diameter of the bar tendon or the number of strands for the strand tendon so that the maximum test load does not exceed the allowable maximum test load for the tendon. The allowable maximum test loads shown in Table 866.04-1 are based on 80 percent of the ultimate strength of the tendon steel.

<table>
<thead>
<tr>
<th>Nominal Diameter</th>
<th>Allow. Max. Test Load</th>
<th>Nominal Diameter</th>
<th>Allow. Max. Test Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>1&quot;</td>
<td>102 kips</td>
<td>26 mm</td>
<td>454 kN</td>
</tr>
<tr>
<td>1 1/4&quot;</td>
<td>150 kips</td>
<td>32 mm</td>
<td>667 kN</td>
</tr>
<tr>
<td>1 3/8&quot;</td>
<td>189 kips</td>
<td>36 mm</td>
<td>844 kN</td>
</tr>
<tr>
<td>1 3/4&quot;</td>
<td>309 kips</td>
<td>46 mm</td>
<td>1378 kN</td>
</tr>
<tr>
<td>2 1/2&quot;</td>
<td>619 kips</td>
<td>65 mm</td>
<td>2758 kN</td>
</tr>
</tbody>
</table>

STRAND TENDONS (ASTM A416)

| Allowable Maximum Test Load = Number of strands × 46.88 kips (208.56 kN) |

If a coupler is required for bar tendons, wrap the coupler with wax tape and cover with a heat shrink sleeve or tape, unless it is for a temporary ground anchor. Do not use couplers for strand tendons.

2. Bond length. Determine the bond length so that every ground anchor meets the specified acceptance criteria. However, do not use a bond length less than 10 ft (3.0 m) for bar tendons and not less than 15 ft (4.5 m) for strand tendons. Make special provisions to transfer the load throughout the bond length when using bond lengths greater than 35 ft (10 m) in rock and greater than 50 ft (15 m) in soil. Do not design the ground anchor so that the total length extends beyond the Right-of-Way or easements.

3. Unbonded length. Use an unbonded length for each ground anchor that is equal to or greater than the unbonded length shown on the Plans, but not less than 10 ft (3.0 m) for bar tendons, and 15 ft (4.5 m) for strand tendons. Do not design the ground anchor so that the total length extends beyond the Right-of-Way or easements.

4. Centralizers and spacers. Place a centralizer within 1 foot (0.3 m) of the bottom of the tendon. Place additional centralizers along the length of the tendon at a maximum spacing of 10 feet (3 m), measured center-to-center. Also place a centralizer within 5 feet (1.5 m) of the top of the bond length. Place spacers for strand tendon no more than 10 feet (3 m) apart within the bond length, with one each located within 5 feet (1.5 m) of the top and bottom of the bond length.
5. **Corrosion Protection.** For corrosion protection of the anchor tendon in the unbonded length, cover the tendon with a sheath filled with either grout or corrosion inhibiting compound. If using a grout filled corrugated sheath (such as an extension of the grout filled, bond length encapsulation) then provide a separate bond breaker over the corrugated sheath.

For corrosion protection of the anchor tendon in the bond length, encase the tendon in a grout filled encapsulation. Ensure there is at least 0.2 inch (5 mm) of grout cover between the tendon and the inside surface of the encapsulation. For bar tendons, ensure that the inside diameter of the encapsulation is at least 0.4 inch (10 mm) greater than the nominal diameter of the bar. For multiple strand tendons, ensure that the area of the strands does not exceed 30 percent of the area defined by the inner diameter of the encapsulation.

Provide continuous corrosion protection at the transition from the bond length to the unbonded length of the anchor tendon.

For bearing plates and anchorage covers that will remain exposed, furnish bearing plates and anchorage covers that are either galvanized or coated with a durable, ultraviolet resistant coating.

The above requirements provide Class I corrosion protection for permanent ground anchors as described in *Recommendations for Prestressed Rock and Soil Anchors* by the Post-Tensioning Institute, 2004. Temporary ground anchors do not require the same level of corrosion protection. The bare tendon encased in the grout provides sufficient corrosion protection. Consider all ground anchors as permanent ground anchors unless they are specifically identified as temporary.

6. **Hole diameter.** Size the hole diameter for the ground anchor to provide sufficient surface area along the grout-ground interface to hold the maximum test load, and at least 0.5 inch (13 mm) grout cover over the encapsulation (or tendon if there is no encapsulation). For multiple strand tendons, ensure that the area of the strands does not exceed 15 percent of the total area of the hole.

7. **Anchor inclination.** Incline the ground anchor as shown on the plans. For ground anchors which support the vertical elements of a retaining wall, the Contractor may modify the anchor inclination shown on the plans under the following conditions:

a. The resulting ground anchor design does not extend beyond the Right-of-Way or easements.
b. The resulting ground anchor design does not conflict with existing or proposed utilities or structures.
c. The Contactor adjusts the anchor load so that the horizontal component of the adjusted maximum test load equals the horizontal component of the plan maximum test load.
d. The Contactor demonstrates that the retaining wall can support any increase in the vertical component of the adjusted maximum test load.
e. The Contactor adjusts the unbonded length so that it extends beyond the critical failure plane by at least 5 feet (1.5 m) or 20 percent of the exposed wall height,
whichever is greater, and so that the resulting ground anchor design ensures the overall stability of the structure.

If choosing to modify the anchor inclination as described above, perform all work required at no additional expense to the Department. Do not modify the anchor inclination shown on the plans for ground anchors which support landslide retaining structures.

8. Anchorage. The trumpet provides a transition from the bearing plate to the anchor tendon corrosion protection. Provide a watertight seal between the trumpet and bearing plate by welding the two together. Provide a trumpet long enough to overlap the corrosion protection in the unbonded length of the tendon by at least 4 inches (100 mm) with a seal between the trumpet and the corrosion protection, or by at least 12 inches (300 mm) without a seal.

Temporary ground anchors do not typically require a trumpet. However, provide a trumpet for temporary ground anchors if one or more of the following conditions exist:

1. Service life of temporary ground anchor will be longer than 24 months.
2. Aggressive ground conditions
3. Cinder, ash, or slag fill
4. Peat or organic soil (A-8a or A-8b)
5. Acid mine drainage or industrial waste.

When providing a trumpet for temporary ground anchors, follow the same requirements as described above for permanent ground anchors. (Note: Using a trumpet for the conditions described above provides Class II corrosion protection as described in Recommendations for Prestressed Rock and Soil Anchors by the Post-Tensioning Institute, 2004.)

B. Submittals. Prepare the following items under the supervision and direction of an Ohio Registered Engineer and have the Registered Engineer sign and seal the items.

1. Shop drawings that show complete details of the ground anchors, including:
   a. Bar tendon size or number of strands
   b. Location of any couplers for bar tendons
   c. Location of centralizers and spacers
   d. Bond length corrosion protection
   e. Unbonded length corrosion protection
   f. Bond breaker in unbonded length
   g. Anchorage and trumpet
   h. Anchorage corrosion protection
   i. Hole diameter
   j. Grout tubes

2. Ground anchor schedule that lists the following for each ground anchor:
   a. Ground anchor number
   b. Bar tendon size or number of strands
   c. Anchor inclination (see below if modifying anchor inclination from plan)
   d. Maximum test load
   e. Lock-off load
f. Unbonded length
g. Bond length
h. Total anchor length

3. Design calculations for bond length

Also, prepare the following items. The items below do not need to be signed and sealed by a Registered Engineer:

4. Anchor installation plan
   a. Drilling procedure and equipment
   b. Hole diameter
   c. Grout mix design
   d. Grouting methods and equipment
   e. Post-grouting procedure, including grout mix and grout pressures (if necessary)

5. Anchor testing plan
   a. Testing equipment, including hydraulic jack, pump, gage, load cell, and displacement gages
   b. Calibration certificates for jack, gages, and load cell
   c. Sample testing forms
   d. Test loads (maximum test load and all test load increments)
   e. Lengths of tendon extensions, jack, load cell, and jacking chair
   f. Procedure for investigative pullout testing (if performed)

Submit the above information to the Engineer at least 30 Calendar days before installing ground anchors. Submit the above information electronically in pdf format or submit four paper copies. Obtain the Engineer’s acceptance of the submittal before beginning ground anchor installation.

If modifying the anchor inclination, then prepare a site plan, cross-sections and calculations under the supervision and direction of an Ohio Registered Engineer as necessary to fulfill the requirement in 866.04.A.7. Have the Registered Engineer sign and seal these items and submit this information to the Engineer at least 30 Calendar days before installing ground anchors. Obtain the Engineer’s acceptance of the submittal before beginning ground anchor installation. Department acceptance of any submittal does not relieve the Contractor of the responsibility for obtaining the required results.

C. Investigative Pullout Testing. The Contractor may choose to perform investigative pullout testing on one or more nonproduction ground anchors in order to help with the design of the production ground anchors. If performing investigative pullout testing, submit the details of the testing program with the rest of the submittal information described above. Install the investigative test anchors and perform the testing before beginning installation of the production ground anchors. The design and installation of the investigative test anchors may or may not be similar to the production anchors. The investigative test anchors do not require any corrosion protection. Do not apply a test load to the investigative test anchors that is greater than 80
percent of the ultimate tensile strength of the tendon steel. Select the location of the investigative test anchors so that the ground conditions are similar to the production anchors. Obtain the Engineer’s acceptance of the location before installing and testing the investigative test anchors. Submit the test results from the investigative pullout testing before beginning installation of the production ground anchors.

If the Contractor makes any modifications to the shop drawings, ground anchor schedule, design calculations, or anchor installation plan after the results of investigative pullout testing, submit the revisions and obtain the Engineer’s acceptance before beginning or resuming ground anchor installation.

866.05 Installation. Select the drilling method, the grouting procedure, and grouting pressures so that every ground anchor meets the specified acceptance criteria. Perform all work according to the shop drawings and anchor installation plan.

A. Drilling. Drill the hole for the ground anchor at the location shown on the Plans. Locate the top of the hole so that the anchor tendon fits within the supported structure as shown on the Plans, but not more than 6 inches (150 mm) in any direction from the plan location. Ensure the inclination of the drill hole is within 3 degrees of the inclination shown on the shop drawings. The Contractor may drill the hole up to 3 feet (1 m) beyond the design length of the tendon in order to provide a place for drill spoils to settle. Provide casing when required to maintain an open hole in unstable soil or rock formations.

B. Anchor Installation and Grouting. Inspect the anchor tendon for signs of damage or corrosion before installation. Anchor tendons with a light coating of rust are acceptable, but do not use anchor tendons that show signs of heavy corrosion or pitting. Clean open holes and cased holes before inserting the anchor tendon and grouting. Insert the anchor tendon in the drill hole and begin grouting no more than 18 hours after drilling the bond length. Do not drive or force the tendon into the drill hole. If the Contractor cannot insert the tendon to the design length, then remove the tendon and clean or redrill the hole to allow insertion. Insert the tendon either before or after grouting. Inject grout at the lowest point of the drill hole by pumping through grout tubes, casing, hollow-stem augers, or drill rods. The Contractor may leave the grout tube in place or withdraw the grout tube during grouting, but ensure that the discharge end of the tube remains below the top of the grout. If leaving the grout tube in place, ensure that it is filled with grout after the completion of grouting.

Fill the hole with grout in one continuous operation, except do not pressure grout in the unbonded length. If the grout at the top of the hole contacts the trumpet or the structure supported by the ground anchors, remove the grout in these areas before it hardens.

C. Post-grouting. If the Contractor installed the ground anchor with a post-grouting system, the Contractor may inject grout under pressure through the post-grouting tube after the initial grout has set. The Contractor may repeat the post-grouting procedure multiple times to increase the anchor capacity.

D. Anchorage Installation. Install the anchor bearing plate and the anchor head or nut perpendicular to the anchor tendon with a tolerance of ±3 degrees. Do not bend or kink the
anchor tendon. For strand tendons, ensure wedges and wedge holes are free of rust, grout, and dirt.

Ensure the trumpet overlaps the corrosion protection in the unbonded length of the tendon by at least 4 inches (100 mm) when a seal is provided between the trumpet and the corrosion protection. When a seal is not provided, ensure the trumpet overlaps the corrosion protection in the unbonded length by at least 12 inches (300 mm). Also ensure the corrosion protection in the unbonded length does not contact the anchor bearing plate or anchor head. If necessary, trim the corrosion protection to prevent contact.

866.06 Testing. Test each ground anchor to demonstrate that it meets the specified acceptance criteria. Conduct performance tests on five percent of the ground anchors but not less than three performance tests. Conduct the specified number of extended creep tests when included in the plans. Conduct proof tests on all ground anchors that are not subject to performance testing or extended creep testing. Performance test the first production ground anchor and then evenly distribute the rest of the performance tests (and extended creep tests, if any) among the remaining ground anchors, or as directed by the Engineer.

During the hold periods for all types of tests, maintain a constant load by adjusting the jack pressure as necessary. Do not allow the jack pressure to drop more than 50 psi (0.35 MPa) during a hold period. Measure and record anchor movement to the nearest 0.001 inch (0.02 mm).

With strand tendons, avoid regripping strands or creating wedge bite marks on the strand below the anchor head. Also with strand tendons, consider the effect of seating losses from the wedges when analyzing displacement measurements.

Do not stand in line with the anchor tendon while testing; only stand to the side of the tendon.

A. Testing Equipment. Provide testing equipment conforming to the following.

1. Provide a hydraulic jack and pump with a rated capacity greater than the maximum test load. Provide a hydraulic jack with a stroke length at least 1 inch (25 mm) greater than the theoretical elastic elongation of the tendon steel at the maximum test load.

2. Provide two pressure gages to measure the pressure in the hydraulic jack – a production gage and a reference gage. Provide pressure gages with graduations of 50 psi (250 kPa) or smaller. Ensure the hydraulic jack and the pressure gages have been calibrated as a unit within 9 months of the beginning of anchor testing. Ensure the calibration is traceable to NIST. Use the reference gage to check the production gage on at least one test per day.

3. Provide a load cell and readout with a rated capacity greater than the maximum test load for extended creep tests. Ensure the load cell and readout have been calibrated as a unit within 9 months of the beginning of anchor testing. Ensure the calibration is traceable to NIST.

4. Provide a displacement gage that can measure movement in increments of 0.001 inch (0.02 mm) or less. Provide a displacement gage with a 4.0 inch (100 mm) minimum range of travel. If the elastic elongation of the tendon steel at the maximum test load will exceed 4.0 inches (100 mm), provide displacement gages with a sufficient range of travel, or provide
multiple displacement gages that can be arranged in series to allow the continuous measurement of the displacement of the anchor head.

5. Provide a jack chair that can transfer 100 percent of the ultimate tensile strength of the tendon steel.

B. Testing Equipment Setup. Position the hydraulic jack, load cell (for extended creep tests), and other necessary items (such as bar extensions, stressing anchorages, and jack chair) over the anchor tendon and parallel to its axis. Apply the alignment load to hold the jack in place.

Set the displacement gage after applying the alignment load. Support the displacement gage on a tripod or other support device that is independent of the ground anchor and the structure. Position the displacement gage so that its axis is parallel to the axis of the anchor tendon within 5 degrees. Check that the stem of the displacement gage is free to move over its entire measurement range.

C. Proof Test. Perform a proof test by incrementally loading and unloading the ground anchor according to the following schedule.

**TABLE 866.06-1 PROOF TEST SCHEDULE**

<table>
<thead>
<tr>
<th>Load Increment for LRFD</th>
<th>Load Increment for ASD</th>
<th>Hold Period (minutes)</th>
<th>Time for Displacement Reading (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AL</td>
<td>AL</td>
<td>---</td>
<td>Initial Reading</td>
</tr>
<tr>
<td>0.20 FDL</td>
<td>0.25 DL</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>0.40 FDL</td>
<td>0.50 DL</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>0.60 FDL</td>
<td>0.75 DL</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>0.75 FDL</td>
<td>1.00 DL</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>0.90 FDL</td>
<td>1.20 DL</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>1.0 FDL</td>
<td>1.33 DL</td>
<td>10 (60) [1]</td>
<td>1, 2, 3, 4, 5, 6, 10 (20, 30, 40, 50, 60) [1]</td>
</tr>
<tr>
<td>AL</td>
<td>AL</td>
<td>---</td>
<td>1</td>
</tr>
</tbody>
</table>

* Hold load just long enough to read displacement, but not longer than one minute
[1] If the amount of movement between the 1 minute and 10 minute displacement readings exceeds 0.04 inch (1 mm), then hold the load for 60 minutes and take additional displacement readings at the times shown in parentheses.

AL = Alignment Load  FDL = Factored Design Load  DL = Design Load
D. **Performance Test.** Perform a performance test by incrementally loading and unloading the ground anchor according to the following schedule.

### TABLE 866.06-2 PERFORMANCE TEST SCHEDULE

<table>
<thead>
<tr>
<th>Load Cycle</th>
<th>Load Increment for LRFD</th>
<th>Load Increment for ASD</th>
<th>Hold Period (minutes)</th>
<th>Time for Displacement Reading (minutes)</th>
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<tr>
<td>1</td>
<td>AL</td>
<td>AL</td>
<td>---</td>
<td>Initial Reading</td>
</tr>
<tr>
<td>2</td>
<td>0.20 FDL</td>
<td>0.25 DL</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>AL</td>
<td>AL</td>
<td>---</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>0.20 FDL</td>
<td>0.25 DL</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>0.40 FDL</td>
<td>0.50 DL</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>0.60 FDL</td>
<td>0.75 DL</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>4</td>
<td>0.20 FDL</td>
<td>0.25 DL</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>0.40 FDL</td>
<td>0.50 DL</td>
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<td></td>
<td>0.60 FDL</td>
<td>0.75 DL</td>
<td>*</td>
<td>*</td>
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<tr>
<td></td>
<td>0.75 FDL</td>
<td>1.00 DL</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>5</td>
<td>0.20 FDL</td>
<td>0.25 DL</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>0.40 FDL</td>
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<td></td>
<td>0.60 FDL</td>
<td>0.75 DL</td>
<td>*</td>
<td>*</td>
</tr>
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<td></td>
<td>0.75 FDL</td>
<td>1.00 DL</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>0.90 FDL</td>
<td>1.20 DL</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>6</td>
<td>0.20 FDL</td>
<td>0.25 DL</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>0.40 FDL</td>
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<td>*</td>
<td>*</td>
</tr>
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<td></td>
<td>0.60 FDL</td>
<td>0.75 DL</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>0.75 FDL</td>
<td>1.00 DL</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>1.0 FDL</td>
<td>1.33 DL</td>
<td>10</td>
<td>1, 2, 3, 4, 5, 6, 10 (60) [1]</td>
</tr>
<tr>
<td></td>
<td>AL</td>
<td>AL</td>
<td>---</td>
<td>1, 2, 3, 4, 5, 6, 10 (20, 30, 40, 50, 60) [1]</td>
</tr>
</tbody>
</table>

* Hold load just long enough to read displacement, but not longer than one minute

[1] If the amount of movement between the 1 minute and 10 minute displacement readings exceeds 0.04 inch (1 mm), then hold the load for 60 minutes and take additional displacement readings at the times shown in parentheses.

AL = Alignment Load  
FDL = Factored Design Load  
DL = Design Load
E. Extended Creep Test. When specified in the Contract Documents, perform an extended creep test by incrementally loading and unloading the ground anchor according to the following schedule. Use a load cell to monitor the load during hold periods.

**TABLE 866.06-3 EXTENDED CREEP TEST SCHEDULE**

<table>
<thead>
<tr>
<th>Load Cycle</th>
<th>Load Increment for LRFD</th>
<th>Load Increment for ASD</th>
<th>Hold Period (minutes)</th>
<th>Time for Displacement Reading (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>AL</td>
<td>AL</td>
<td>10</td>
<td>1, 2, 3, 4, 5, 6, 10</td>
</tr>
<tr>
<td>2</td>
<td>0.20 FDL</td>
<td>0.25 DL</td>
<td>30</td>
<td>1, 2, 3, 4, 5, 6, 10, 15, 20, 25, 30</td>
</tr>
<tr>
<td>3</td>
<td>0.40 FDL</td>
<td>0.50 DL</td>
<td>30</td>
<td>1, 2, 3, 4, 5, 6, 10, 15, 20, 25, 30</td>
</tr>
<tr>
<td>4</td>
<td>0.60 FDL</td>
<td>0.75 DL</td>
<td>45</td>
<td>1, 2, 3, 4, 5, 6, 10, 15, 20, 25, 30</td>
</tr>
<tr>
<td>5</td>
<td>0.75 FDL</td>
<td>1.00 DL</td>
<td>60</td>
<td>1, 2, 3, 4, 5, 6, 10, 15, 20, 25, 30</td>
</tr>
<tr>
<td>6</td>
<td>0.90 FDL</td>
<td>1.20 DL</td>
<td>90</td>
<td>1, 2, 3, 4, 5, 6, 10, 15, 20, 25, 30</td>
</tr>
<tr>
<td>7</td>
<td>1.0 FDL</td>
<td>1.33 DL</td>
<td>300</td>
<td>75, 90, 100, 120, 150, 180, 210, 240, 270, 300</td>
</tr>
</tbody>
</table>

* - Hold load just long enough to read displacement, but not longer than one minute

AL = Alignment Load  
FDL = Factored Design Load  
DL = Design Load
F. Acceptance Criteria. A ground anchor is acceptable when it holds the maximum test load and it meets the acceptance criteria for creep movement and apparent free length during testing.

1. Creep movement. Creep movement of a ground anchor is the displacement of the anchor head under a relatively constant load during the hold period of the test. However, it does not include the creep displacement of the tendon itself.

The acceptance criteria for ground anchors subject to proof or performance testing is no more than 0.04 inches (1 mm) of creep movement between the 1 and 10 minute displacement readings, or no more than 0.08 inches (2 mm) of creep movement between the 6 and 60 minute displacement readings.

The acceptance criteria for ground anchors subject to extended creep testing is no more than 0.08 inches (2 mm) of creep movement in the last log cycle of time for each hold period. A log cycle of time is the time between two displacement readings where the second reading is at a time ten times longer than the time of the first reading (for example, 1 minute to 10 minutes, 6 to 60 minutes, and 30 to 300 minutes are each one log cycle of time).

Tendons which have not been proof stretched may require adjustments to the creep displacement readings to account for the creep of the tendon steel. Determine necessary adjustments from test results furnished by the tendon supplier.

2. Apparent Free Length. The apparent free length of a ground anchor is the equivalent length of the tendon steel that has the same elongation as the measured elastic movement under the same net load (the test load minus the alignment load). Calculate the apparent free length at the maximum test load in a proof test and at the maximum test load in each load cycle in a performance test or extended creep test. Use the following equation to calculate the apparent free length.

\[
\text{Apparent Free Length} = \frac{A \times E \times d}{T_L - AL}
\]

Where:
- \(A\) = cross-section area of the tendon steel
- \(E\) = modulus of elasticity of the tendon steel
- \(d\) = elastic movement (displacement reading at the test load minus the subsequent displacement reading at the alignment load)
- \(T_L\) = test load
- \(AL\) = alignment load

The acceptance criteria for the apparent free length is at least 80 percent of the unbonded length of the ground anchor plus the jack length.

If a ground anchor does not meet this acceptance criteria, but it can hold the maximum test load and it meets the acceptance criteria for creep movement, then repeat the test load cycle. Reduce the test load to the alignment load and then incrementally increase the test load to the maximum test load according to the proof test schedule. If the ground anchor fails to meet the apparent free length acceptance criteria on the second attempt, repeat the test load cycle a third
time. If after three attempts the ground anchor still fails to meet the apparent free length acceptance criteria, then replace the ground anchor.

**G. Ground Anchors Not Meeting Acceptance Criteria.** When a ground anchor does not meet the acceptance criteria, correct the problem at no expense to the Department. The corrections may include, but are not limited to, post-grouting the ground anchor, replacing the unacceptable ground anchor, reducing the anchor design load and installing additional ground anchors, changing anchor inclination, changing installation methods, or increasing anchor total length or anchor bond length.

Ground anchors that do not meet one of the acceptance criteria may still be incorporated into the Work under the following conditions.

1. If the ground anchor cannot hold the maximum test load, and the Contractor installed the ground anchor with a post-grouting system (i.e. a regrout tube), then the Contractor may post-grout the ground anchor and repeat the testing using the original acceptance criteria.

2. If the ground anchor holds the maximum test load but does not meet the acceptance criteria for creep movement at the maximum test load, and the Contractor installed the ground anchor with a post-grouting system (i.e. a regrout tube), then the Contractor may post-grout the ground anchor and repeat the testing using an enhanced acceptance criteria for creep movement. The enhanced acceptance criteria consists of no more than 0.04 inches (1 mm) of creep movement between the 1 and 60 minute displacement readings at the maximum test load.

3. If the ground anchor does not meet the acceptance criteria for creep movement or if it cannot hold the maximum test load, the Contractor may use the ground anchor with a reduced load. Lock off the ground anchor at no more than 50 percent of the stabilization load (the load that the anchor holds without detectable movement at the end of testing). To determine the stabilization load, stop adjusting the jack pressure, wait until the displacement reading has not changed for 10 minutes, and then measure the load in the anchor. When incorporating a ground anchor into the Work in this manner, install additional ground anchors or use some other corrective procedure to compensate for the reduced anchor load.

Except for items 1 and 2 above (post-grouting), submit the proposed corrective work to the Engineer in writing before beginning corrective work. However, if the proposed corrective work includes installing additional ground anchors at different locations than shown in the Plan, changing the anchor loads or changing the locations of ground anchors, prepare and submit a Corrective Work Plan (CWP) according to 501.05.D. Obtain Department acceptance of the CWP before performing corrective work.

**866.07 Anchor Lock-off**

**A. Bar Tendons.** After testing, adjust the load on the ground anchor to the specified lock-off load and then increase the load to compensate for seating losses. Transfer the load from the jack to the anchorage device. Before removing the jack, perform a lift-off test to confirm the load in the anchor tendon. Perform the lift-off test by re-applying load to the anchor tendon until the anchor nut lifts off the bearing plate. The lift-off reading must be within five percent of the specified lock-off load. If the lift-off reading is not within five percent of the specified lock-off load, repeat the lock-off procedure and lift-off tests until it is within five percent.
B. Strand Tendons. After testing, adjust the load on the ground anchor to the specified lock-off load but not less than the minimum seating load which is 50 percent of the ultimate strength of the strand tendons. Determine the minimum seating load for strand tendons using the following equation.

Minimum Strand Seating Load = Number of strands × 29.30 kips (130.35 kN)

Increase the load as necessary to compensate for seating losses. If the specified lock-off load is less than the minimum seating load, use shims under the wedge plate so that the wedges are seated at the minimum seating load and then remove the shims to reduce the load on the ground anchor to the specified lock-off load. Transfer the load from the jack to the anchorage device. Before removing the jack, perform a lift-off test to confirm the load in the anchor tendon. Perform the lift-off test by re-applying load to the anchor tendon until the wedge plate lifts off the bearing plate or the wedges lift. The lift-off reading must be within five percent of the specified lock-off load. If the lift-off reading is more than five percent below the specified lock-off load, increase the lock-off load by lifting the anchor head and placing shims under the anchor head. If the lift-off reading is more than five percent above the specified lock-off load, notify the Engineer and adjust the procedures to ensure this does not occur on subsequent ground anchors.

C. Bar and Strand Tendons. Cut off excess tendon steel leaving at least 0.5 inch (13 mm) extending above the wedges or anchor nut. For permanent anchors, completely fill the trumpet with grout. Take adequate precautions to prevent grout from freezing. For permanent anchors that require an anchorage cover, ensure the cover fits over the anchor head and seals against the bearing plate. Completely fill the cover with grout.

866.08 Method of Measurement. The Department will measure the quantity of Ground Anchors and Temporary Ground Anchors by the number of each anchor that is installed and accepted. The Department will measure the quantity of Performance Tests and Extended Creep Tests by the number of successful tests performed on ground anchors that meet the acceptance criteria.

866.09 Basis of Payment. The Department will pay for a testing item after the Contractor submits a written test report for that testing item. Include the cost of proof testing in the contract unit price for Ground Anchors.

If a pay item for Investigative Ground Anchor Pullout Tests is not included in the Contract for payment, and the Contractor chooses to perform this testing, include the cost of the investigative testing in the unit price bid for the ground anchors.

The Department will pay for accepted quantities at the contract price as follows:

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>866</td>
<td>Each</td>
<td>Ground Anchor, ___ kip Max. Test Load</td>
</tr>
<tr>
<td>866</td>
<td>Each</td>
<td>Temporary Ground Anchor, ___ kip Max. Test Load</td>
</tr>
<tr>
<td>866</td>
<td>Lump Sum</td>
<td>Investigative Anchor Pullout Tests</td>
</tr>
<tr>
<td>866</td>
<td>Each</td>
<td>Performance Test</td>
</tr>
<tr>
<td>866</td>
<td>Each</td>
<td>Extended Creep Test</td>
</tr>
</tbody>
</table>
**Designer Note:** Under this supplemental specification, the Contractor determines the bond length for the ground anchor in order to hold a specified maximum test load. Therefore **DO NOT** give a bond length or a minimum bond length in the plans. The required minimum bond lengths for bar tendons and strand tendons are given in the specification and should not be repeated in the plans.

<table>
<thead>
<tr>
<th>Show in plans</th>
<th>DO NOT show in plans</th>
</tr>
</thead>
<tbody>
<tr>
<td>location (horizontal and vertical) of the anchor head</td>
<td>bond length</td>
</tr>
<tr>
<td>anchor inclination</td>
<td>total anchor length</td>
</tr>
<tr>
<td>minimum unbonded length</td>
<td>tendon type and size</td>
</tr>
<tr>
<td>maximum test load</td>
<td>minimum hole diameter</td>
</tr>
<tr>
<td>lock-off load</td>
<td></td>
</tr>
</tbody>
</table>

Because you need to specify the maximum test load for each ground anchor, you must perform a preliminary design, including a preliminary estimate of the bond length, to determine a reasonable value for the maximum test load. Determine the design load or factored design load for ground anchors according to either Section 5.7 of the AASHTO Standard Specifications for Highway Bridges, 17th edition, 2002 or Section 11.9 of the latest edition of the AASHTO LRFD Bridge Design Specifications.

The maximum test load is equal to the factored strength load for LRFD and equal to 1.33 times the design load for ASD. For LRFD, note that the resistance factor for pullout of ground anchors is 1.0, since every ground anchor will be proof tested. However, the pullout resistance factors for preliminary design vary from 0.5 to 0.7, so the preliminary design will tend to be conservative. For preliminary design, use the information from the geotechnical exploration to determine appropriate presumptive bond stresses and use bond lengths of 20 to 50 feet.

After determining the maximum test load, determine the appropriate lock-off load for the ground anchor. The lock-off load is typically 85 to 100 percent of the design load (ASD) or service load (LRFD). However, you must also consider the construction sequence of the structure and the bending moments and movement of the wall that will occur when the lock-off load is applied. For example, lock-off loads at 85 percent of the design load may be used for temporary support of excavation systems where relatively large lateral wall movements are permitted. Generally, specify the lock-off load at 100 percent of the design load or service load so that the lock-off load will usually be greater than 50 percent of the ultimate strength of the tendon, as this is important for strand tendons. However, recognize that this may result in some net inward movement of the wall, especially for the top row of ground anchors, because apparent earth pressure diagrams result in loads greater than actual soil loads. Also, lock-off loads greater than 100 percent of the design load may be required to stabilize a landslide. However, the lock-off load must not be more than 1.16 the design load (for ASD) or not more than 0.875 FDL (for LRFD), in order to avoid overstressing the tendon steel.

To simplify construction, attempt to minimize the number of ground anchors with different maximum test loads. When using more than one maximum test load value, include a different pay item for each ground anchor with a different maximum test load value.
If the anchor head of a permanent ground anchor will be encased in concrete with sufficient cover (generally 2.0-inch minimum), then an anchorage cover is not required. Otherwise, show permanent ground anchors with an anchorage cover in the cross-sections and details.

Estimate the number of performance tests by multiplying the number of ground anchors by 5 percent, but include at least three performance tests.

Extended creep tests are only performed if a pay item is included in the contract for them. Include two extended creep tests for permanent ground anchors where the bond length is either in cohesive soil with a plasticity index greater than 20 or a liquid limit greater than 50, or in very decomposed or weak argillaceous rock.

Provide a pay item for investigative anchor pullout tests when one or more of the following conditions exist:

1. Extended creep tests will be performed,
2. The preliminary design of the ground anchors assumed bond stresses greater than the average bond stress typical for the soil or rock conditions, or
3. The project requires the installation of a large number of ground anchors, especially when there are varying loads on different anchors.

Note that even without a pay item for the investigative anchor pullout testing, the contractor may still perform the testing. However, the cost of the testing will then be included in the unit bid price for the ground anchors.

**Ground anchors in karst or other rock formations with open fractures**

When the geotechnical exploration for a project indicates that the bond length for the ground anchors will be in a rock formation that has open fractures (like karst), artesian water, or when there was interconnection between borings, use the following plan note and pay items. Estimate the quantity of redrilling based on one each for every ground anchor. Estimate a reasonable quantity of cubic yards of grout for pre-grouting based on the amount of grout used to backfill the borings.

**ITEM 866 Pre-grouting Ground Anchors in Rock.** When the ground anchor will be installed in a rock formation that has open fractures, when there is water flow or seepage through the rock formation, when there is interconnection between drill holes, or when there is reason to believe grout may be lost from around the tendon bond length, pre-grout anchor holes after drilling with neat cement grout or sanded grout as necessary in order to maintain grout at the top of the hole until it sets. After the pre-grout sets, redrill the hole and install the ground anchor as specified. The Contractor may also use grout socks at no expense to the Department to help maintain grout in the hole.

The Department will measure the quantity of Pre-Grouting in Rock by the number of cubic yards acceptably placed based on the volume pumped. The Department will measure the quantity of Redrilling Pre-Grouted Holes in Rock by the number of times the Contractor redrills the anchor hole after pre-grouting.
ITEM 866 _____ Cubic Yards  Pre-Grouting in Rock
ITEM 866 _____ Each  Redrilling Pre-Grouted Holes in Rock

**Restressable Ground Anchors**
Generally, it is not necessary to restress most ground anchors during their service life. However, it may be necessary when movement of the structure or ground will greatly increase or decrease the load in the anchor. In this case, use the following plan note to specify restressable ground anchors. Edit the plan note as necessary for the project.

**ITEM 866  Ground Anchors, As Per Plan.** Install permanent ground anchors that can be restressed after installation. Leave enough tendon steel extending above the wedges or anchor nut to allow restressing. Fill the trumpet and anchorage cover with corrosion inhibiting compound instead of grout after testing. Provide a seal between the trumpet and the corrosion protection in the unbonded length of the anchor tendon to prevent the corrosion inhibiting compound from leaking.

**References**
For additional guidance, refer to the following publications.