May 25, 2017

REVISION OF SECTION 504

SOIL NAIL WALL

**NOTICE**

This is a standard special provision that revises or modifies CDOT’s *Standard Specifications for Road and Bridge Construction.* It has gone through a formal review and approval process and has been issued by CDOT’s Project Development Branch with formal instructions for its use on CDOT construction projects. It is to be used as written without change. Do not use modified versions of this special provision on CDOT construction projects, and do not use this special provision on CDOT projects in a manner other than that specified in the instructions unless such use is first approved by CDOT’s Standards and Specifications Unit. The instructions for use on CDOT construction projects appear below.

Other agencies which use the *Standard Specifications for Road and Bridge Construction* to administer construction projects may use this special provision as appropriate and at their own risk.

**Instructions for use on CDOT construction projects:**

Use in projects having a soil nail wall.

Section 504 of the Standard Specifications is hereby deleted for this project and replaced with the following:

**DESCRIPTION**

1. This work consists of constructing a permanent soil nailed wall (also referred to as ground nail wall) as specified herein, and as shown on the plans. Temporary soil nail walls and the final facing are not covered in this specification. The work includes:
2. Excavating staged lifts in accordance with the plans and approved submittals.
3. Drilling soil nail holes to the diameter and length required to develop the specified capacity as shown on the plans.
4. Installing soil nails including placement and grouting.
5. Performing soil nail testing and providing test results to the Engineer.
6. Providing and installing the specified drainage features.
7. Providing and installing bearing plates, washers, nuts, couplers, and other required miscellaneous materials.
8. Constructing the initial shotcrete face.

**MATERIALS**

1. Materials shall meet the following requirements:
2. Concrete shall be Class D, conforming to the requirements of Section 601.
3. Reinforcing Steel shall conform to the requirements of Section 602.
4. Shotcrete shall conform to the requirements of Section 641.
5. Forms and falsework shall conform to the requirements of subsections 601.09 and 601.11.
6. Geocomposite strip drains shall comply with Section 712.12.
7. Underdrains and pipes shall comply with Sections 712.11 and 712.13.
8. **Soil Nails**
9. *Solid Bar Soil Nail.* Bars shall conform to AASHTO M31 for Grade 75 or ASTM A 722 for Grade 150. Bars shall be threaded, continuous without splices or welds, new, straight, undamaged, epoxy-coated or encapsulated as shown on the plans. Bars shall be threaded a minimum of 6 inches on the wall anchorage end to allow proper attachment of bearing plate and nut. Threading may be continuous spiral deformed ribbing provided by the bar deformations (continuous thread bars) or may be cut into a reinforcing bar. If threads are cut into a reinforcing bar, the next-larger bar number designation from that shown on the plans shall be provided at no additional cost.
10. *Bar Coupler.* Bar couplers, where allowed by the plans, shall be designed to develop the full ultimate tensile strength of the bar as certified by the manufacturer.
11. *Fusion Bonded Epoxy Coating.* Epoxy coating for bars and end hardware shall conform to ASTM A775 or A934. The minimum thickness shall be 0.012 inch and shall be electrostatically applied. Bend test requirements are waived. Coating at the wall anchorage end of epoxy-coated bars may be omitted over the length provided for threading the nut against the bearing plate. Coating at the end of the bar of epoxy-coated bars may be omitted over the length provided for threading a coupler if bars are to be joined. Galvanization may be substituted for epoxy. Bars should be galvanized according to ASTM A767/A767M. A minimum galvanization coating of 3.4-mil thickness is required. Galvanization shall be applied in accordance with ASTM A153 for nuts, plates, and other hardware.
12. *Encapsulation.* Encapsulation shall be a sheathing of either corrugated HDPE tube with a minimum 0.06-inch thickness conforming to AASHTO M252 or corrugated PVC tube with a minimum 0.04-inch thickness conforming to ASTM D1784, Class 13464-B. The level of corrosion protection shall be as shown on the plans.
13. *Centralizer.* Centralizers shall be manufactured from Schedule 40 PVC pipe or tube, or other material not detrimental to the soil nail steel or corrosion protection. Wood shall not be used. Centralizers shall be
	1. Securely attached to the soil nail bar.
	2. Sized to position the soil nail bar within 1 inch of the center of the drill hole.
	3. Sized to allow tremie pipe, grout tube, or casing insertion along the full length of the drill hole.
	4. Sized to allow grout to freely flow up the drill hole.
14. *Soil Nail Grout*. The minimum compressive strength for grout should be 1,500 pounds per square inch (psi) at 3 days, and 3,000 psi at 28 days, as tested in accordance with ASTM C109. If sand is used in the grout mixture, it shall meet the requirements of subsection 703.02. A batch ticket shall be supplied for each grout delivery to be used during construction of the soil nail wall. If grout is mixed on site, all materials shall be weighed and recorded prior to mixing or incorporation into the mixer. The water/cementitious ratio and specific gravity may be used as a primary quality control of the neat cement grout mix if the Contractor can demonstrate the materials and mix design consistently produce a grout of the minimum specified strength. Neat cement grout cubes shall be molded and tested on the grout used in production soil nails and the adjacent test soil nail.
15. *Fine* *Aggregate*. Fine aggregate shall conform to subsection 703.02.
16. *Cementitious* Materials. Cementitious materials shall conform to Section 701. The cement used for shotcrete and grout shall meet the sulfate resistance requirements of subsection 601.04.
17. *Admixtures*. Admixtures shall conform to Section 711. Admixtures that control bleed, improve flowability, reduce water content, reduce washout, and retard set may be used in the grout as approved by the Engineer. Accelerators are not permitted. Expansive admixtures may be used only in grout used for filling sealed encapsulations. Admixtures shall be compatible with the grout and mixed in accordance with the manufacturer’s recommendations.
18. *Film Protection.* Polyethylene film for moisture loss control shall conform to AASHTO M171.
19. **Bearing Plates, Washers, Nuts, and Headed Studs.**

(a) *Bearing Plates.* Bearing plates shall conform to AASHTO M183/ASTM A36.

(b) *Beveled Washers*. Beveled washers shall conform to ASTM F436, with an angle matching the inclination of the soil nail to provide uniform bearing.

(c) *Nuts*. Nuts shall be hexagonal and fitted with beveled washer or spherical seat to provide uniform bearing to develop the full ultimate tensile strength of the bar as certified by the manufacturer and conform to AASHTO M292/ASTM A194. ,.

(d) *Headed Studs*. Headed studs on the bearing plate shall conform to requirements of Section 509.12.

1. **Welded Wire Fabric.** Welded Wire Fabric shall conform to AASHTO M55, AASHTO M221, or ASTM A1064.

**CONSTRUCTION REQUIREMENTS**

1. **Contractor Qualifications.** The Contractor shall provide on-site supervisors and drill operators with experience installing permanent soil nails on at least 3 permanent soil nail retaining wall projects during the past 3 years totaling at least 10,000 square feet of wall face area and at least 500 permanent soil nails.
2. **Submittals.** The following documents shall be submitted in accordance with subsection 105.02. No work relating to soil nail wall construction including ordering materials shall be performed before the following submittals have been reviewed and reviewed by the Engineer.
3. *Qualifications*. The soil nailing Contractor shall submit a brief description of at least 3 completed projects, including the owning agency’s name, address, current phone number, location of project, project contract value, square foot of wall, the number of nails, scheduled completion date, and actual completion date for the project.
4. *Personnel*. At least 14 calendar days before starting soil nail work, the soil nailing Contractor shall identify on-site supervisors, and drill operators assigned to the project, and submit a summary of each individual’s experience. Only those individuals designated as meeting the qualifications requirements shall be used for the project. The soil nailing Contractor shall not substitute for any of these individuals without written approval by the Engineer. The Engineer will review the soil nailing Contractor qualifications and staff within 15 working days after receipt of the submission. The Engineer may suspend the work if the soil nailing Contractor substitutes unqualified personnel for qualified personnel during construction. If work is suspended due to the substitution of unqualified personnel per subsection 504.06, the Contractor shall be fully liable for additional costs resulting from the suspension of work and no adjustment in contract time resulting from the suspension of the work will be allowed.
5. *Construction Plan*. At least 14 days before starting soil nail work, the soil nailing Contractor shall submit a Construction Plan to the Engineer for review that includes the following:
6. The start and finish date and proposed detailed wall construction sequence. Include schedule entries and anticipated durations for each lift excavation, soil nail installation for each lift, grout curing, soil nail testing, and shotcrete placement and curing.
7. Drilling and grouting methods and equipment, including the drill hole diameter proposed to achieve the specified pullout resistance values shown on the plans and any proposed variation of these along the wall alignment.
8. Soil nail grout mix design, including compressive strength test results supplied by a qualified independent testing lab verifying the specified minimum 3-day and 28-day grout compressive strengths. Previous test results for the same grout mix completed within one year of the start of grouting may be submitted for verification of the required compressive strengths.
9. Soil nail grout placement procedures and equipment.
10. Shotcrete materials and methods including methods to address soil fall out, perched water, and anti-washout as needed based on site condition or review of the Geotechnical Report in accordance with subsection 102.05.
11. All materials, methods, and control procedures for the initial shotcrete facing.
12. Soil nail testing methods and equipment setup.
13. Identification number and certified calibration records for each test jack, pressure gauges, and load cell to be used. Jack, load cell, and pressure gauge shall be calibrated as a unit. Calibration records shall include the date tested, the device identification number, and the calibration test results and shall be certified for an accuracy of at least 2 percent of the applied certification loads by a qualified independent testing laboratory within 6 months prior to submittal.
14. Certificates of Compliance for:
	1. The soil nail bar yield or ultimate tensile strength.
	2. Soil nail bar steel type.
	3. Bearing plates, washers, nuts, and couplers.
	4. Corrosion protection.
	5. Geocomposite strip drain and underdrain material.

The Engineer will review the soil nailing Contractor’s Construction Plan within 10 working days after the submission.

1. **Protection and Cleanup.** During work operations, the Contractor shall take such precautions as may be necessary to prevent shotcrete overspray, drill cuttings, equipment exhaust, oil, wash water, and other materials from defacing or damaging private and public property including adjacent landscaping in accordance with subsections 107.12 and 107.25. The Contractor shall furnish all equipment as may be necessary to handle waste water and material from the operations, and clean up all waste resulting from the operations. The Contractor is responsible for the stability of the highway facility and nearby structures.
2. **Storage and Handling.** Soil nail bars shall be stored and handled in a manner to avoid damage, excessive bending, permanent deformation, or corrosion. Bars exhibiting abrasions, cuts, welds, weld splatter, corrosion, or pitting shall be replaced. Bars exhibiting damage to encapsulation or epoxy coating shall be repaired or replaced. Repaired epoxy coating areas shall have a minimum 0.012-inch thick coating. Bars exhibiting damage shall be repaired or replaced at the Contractor’s expense.
3. **Excavation.** The Contractor shall be responsible for providing the necessary survey and alignment control during the excavation for each lift, locating drill holes, and verifying limits of the soil nail wall installation. Prior to any excavation, surface water controls shall be installed around the wall area as needed to prevent surface water, seepage, or springs from flowing within or into the excavation or as determined by the Engineer. The Engineer shall be notified 14 days prior to the beginning of excavation to allow scheduling of qualified representatives of the soil nail wall design professional engineer to observe the excavation and drilling as needed. The Engineer and the soil nail wall design engineer shall be contacted immediately if the Contractor encounters any ground conditions or materials during the excavation or drilling that is not shown on the plan set or unanticipated seepage, springs, or other sources of groundwater to allow for review of the design. The Contractor shall reference available Geotechnical Reports or other site condition reports in accordance with subsection 102.05 for additional information concerning the ground conditions that are anticipated during excavation.

During construction of the soil nail wall, excavation not associated with the soil nail wall construction shall not be performed within a horizontal distance equal to the total height of the final soil nail wall face excavation. The height of the exposed unsupported final excavation face cut shall not exceed the vertical soil nail spacing plus the required reinforcing lap or the short-term stand-up height of the ground, whichever is less. Each lift excavation shall be completed to the final wall excavation line and shotcrete applied in the same work shift, unless otherwise approved by the Engineer. Application of the shotcrete may be delayed up to 24 hours if the Contractor can demonstrate that the delay will not adversely affect the excavation face stability.

The Contractor shall modify excavation procedures and soil nail wall installation procedures to prevent the loss of material from the excavation face or from behind the previously installed shotcrete lift (chimneying). This may require adjustments to the sequencing between excavation, soil nail drilling and shotcreting to shorten the time the excavation lift is unsupported, drilling and installing the soil nails through temporary berms prior to final excavation and/or installing the initial shotcrete prior to drilling the soil nails. All voids that develop behind the shotcrete shall be filled with grout at no additional cost to the Department.

Excavation of the next-lower lift shall not proceed until soil nail installation, initial shotcrete face placement, attachment of bearing plates and nuts, and soil nail testing have been completed and accepted per subsection 504.17 in the current lift. Soil nail grout and shotcrete shall have achieved a compressive strength of at least 1000 psi before excavation of the next underlying lift.

Where the Contractor’s excavation and installation methods result in a discontinuous wall along any soil nail row, the ends of the upper lift excavation shall extend beyond the ends of the next lower excavation lift by at least 10 feet. Slopes at these discontinuities shall be constructed to prevent sloughing or failure of the temporary slopes. If sections of the wall are to be constructed at different times, the Contractor shall prevent sloughing or failure of the temporary slopes at the end of each wall section.

The Contractor shall remove all or portions of cobbles, boulders, rubble or other subsurface obstruction encountered at the cut line which will protrude in to the shotcrete facing including a method to safely secure remnant pieces remaining behind the excavation face and promptly backfilling voids resulting from removal of protrusions extending behind the excavation face. Voids, over-break or over-excavation beyond the plan wall excavation line resulting from the removal of face protrusions or the excavation operation shall be backfilled with shotcrete, concrete, or grout.

1. **Soil Nail Installation.** Soil nail length and drill hole diameter used shall be those necessary to develop the specified load capacity to satisfy the acceptance criteria, but not less than the lengths or diameters shown on the plans. The Contractor shall modify their drilling procedures, as needed, to achieve the required soil nail pullout resistance specified in the plans. All work required to achieve the required soil nail pullout resistance including modifications to the drilling procedures will not be measured separately but shall be included in the unit price of the work. Holes shall be drilled for the soil nails at the locations, elevations, orientations, and minimum lengths shown on the plans. Drilling equipment and methods shall be suitable for the ground conditions and conform to the installation methods submitted by the soil nailing Contractor. Drilling muds or other fluids shall not be used to remove cuttings. If caving ground is encountered, cased drilling methods shall be used to support the sides of the drill holes. Self-drilling soil nail bars (also known as hollow, self-grouting or pressure grouted soil nail bars) shall not be used unless indicated on the plans. Soil nail bars shall be as shown on the plans. Provide centralizers per Section 504.03 (e).
2. **Grouting.** The drill hole shall be grouted after installation of the soil nail bar and within 2 hours of completion of drilling. The grout shall be injected at the lowest point of each drill hole through a tremie pipe, grout tube, or casing. The outlet end of the grout tube or casing shall be kept below the surface of the grout as the conduit is withdrawn to prevent the creation of voids. The drill hole shall be completely filled in one continuous operation. Cold joints in the grout column are not allowed except at the top of the test bond length of proof tested production soil nails. Excessive grout take is defined as twice the theoretical grout volume to grout the drill hole. The Engineer shall be notified of excessive grout take to allow for modification of the wall design and construction. The Contractor shall maintain the stability of borings through the temporary unbonded length of proof test soil nails for subsequent grouting. If the unbonded test length of production proof test soil nails cannot be satisfactorily grouted subsequent to testing, the Contractor shall install a new soil nail in its place.

In some granular soils with an open matrix with no cohesion, the potential for drill hole collapse or grout leakage may be large. In this case, the a grout containment device or “sock” may be used as approval by the Engineer to reduce excessive grout take in the highly-permeable soil.

1. **Underdrain.** The underdrain shall be installed in accordance with Section 605.03. The underdrain should be installed as part of the soil nail wall construction. If the underdrain is to be installed at a time after construction of the soil nail wall, the Contractor shall notify the Engineer to review any proposed excavation at the foot of the wall for stability.

**Soil Nail Testing.** Both verification and proof testing of designated test soil nails shall be performed. Proof tests shall be performed on production soil nails at locations selected by the Engineer or as shown on the plans. Testing of a soil nail shall not be performed until the soil nail grout and shotcrete facing have cured for at least 72 hours or attained their specified 3-day compressive strength.

The Contractor shall provide all necessary equipment to perform the soil nail testing including, but not limited to, dial gauges, dial gauge support, jack and pressure gauge, electronic load cell with machined platens placed at either end of the load cell, and a reaction frame. In non-creep susceptible soils and as approved by the Engineer, the use of a load cell may be replaced with a dual pressure gauge system with the low reading gauge being used for soil nail acceptance.

The pressure gauge shall be graduated in 100 psi increments or less. The soil nail head movement shall be measured with a minimum of 2 dial gauges capable of measuring to 0.001 inch. The Contractor shall have available calibrated back up gauges and test loading equipment to minimize down time due to testing equipment failure.

The Contractor shall not apply loads greater than 80 percent of the minimum ultimate tensile strength of the tendon for Grade 150 bars or 90 percent of the yield strength of the tendon for Grade 75 bars. Preliminary results shall be submitted to the Engineer within 24 hours of the test completion. A full report containing test load results shall be submitted to the Engineer within 5 working days of the test completion.

1. **Verification Testing Of Sacrificial Soil Nails.** Verification testing shall be performed on sacrificial test soil nails as shown on the plans. Verification testing shall be performed prior to installation of production soil nails to confirm the appropriateness of the Contractor’s drilling and installation methods, and verify the required soil nail pullout resistance.

Verification test soil nails shall have both bonded and unbonded lengths. Along the unbonded length, the soil nail bar shall not be grouted. The unbonded length of the test soil nails shall be at least 3 feet as measured from the back of the bearing plate to the top of the grout.

Verification tests shall be conducted according to the loading schedule of Table 504-1. Each load increment shall be held for at least 10 minutes. The Contractor shall record soil nail movements at each load increment and the time intervals shown in the table for each load step. Creep tests shall be performed at 0.75 VTL. The alignment load (AL) should be the minimum load required to align the testing apparatus and shall not exceed 5 percent of the VTL. The dial gauges shall be set to “zero” after applying the alignment load. Following application of the maximum load, the load shall be reduced to the alignment load and the dial gauge readings recorded as the permanent set.

Each load increment shall be held for at least 10 minutes. The Contractor shall monitor the verification test soil nail for creep at the 0.75 VTL load increment by measuring and recording soil nail movement. The load shall be maintained during the creep test within 2 percent of the intended load by use of the load cell. The test results shall be presented for the Engineers review and acceptance prior to production. The Engineer shall have 10 working days to review the report and based on the results, design modifications may be required.

The bonded length of the soil nail during verification tests (LB VT) shall be:

1. For Grade 75 and other mild steel in accordance with ASTM A615, the maximum bond length (LB VTmax), is defined as:

$$L\_{B VTmax} = \frac{A\_{t}∙f\_{y}∙C\_{RTY}}{r\_{PO}}$$

1. For Grade 150 and other high-strength steel in accordance with ASTM A722, the maximum bond length (LB VTmax), is defined as:

$$L\_{B VTmax} = \frac{A\_{t}∙f\_{u}∙C\_{RTU}}{r\_{PO}}$$

where:

CRTY = reduction coefficient for mild-grade steel = 0.9

CRTU = reduction coefficient for high-strength steel = 0.8

At = cross-sectional steel area of the test soil nail in square inches

fy = nominal yield strength of test soil nail (mild steel) in kips per square inch

fu = nominal tensile strength of test soil nail (high-strength steel) in kips per square inch

rPO = nominal pullout resistance in kips per foot of test soil nail per plans = π × qu × DDH

qu = nominal bond strength in kips per square foot

DDH = drill hole diameter in feet

1. If LB VTmax > 10 feet, select LB VT to be 10 feet ≤ LB VT ≤ LB VTmax.
2. If LB VTmax < 10 feet, to avoid tensile breakage, select LB VT = 10 feet and increase the test soil nail bar size as needed, and recalculate LB VTmax until LB VTmax > 10 ft.
3. The maximum (nominal) load during the verification test is defined as the Verification Test Load (VTL) and is calculated as VTL = LB VT × rPO

**Table 504-1**

**VERIFICATION TEST LOADING SCHEDULE**

|  |  |
| --- | --- |
| **Load** | **Hold Time (minutes)2** |
| AL1 | 1 |
| 0.13 VTL | 10 (recorded at 1, 2, 4, 5, 10) |
| 0.25 VTL | 10 (recorded at 1, 2, 4, 5, 10) |
| 0.38 VTL | 10 (recorded at 1, 2, 4, 5, 10) |
| 0.50 VTL | 10 (recorded at 1, 2, 4, 5, 10) |
| 0.63 VTL | 10 (recorded at 1, 2, 4, 5, 10) |
| 0.75 VTL (Creep Test)3 | 60 (recorded at 1, 2, 4, 5, 6, 10, 20, 30, 50, 60) |
| 0.88 VTL | 10 |
| 1.00 VTL4 | 10 |
| AL | 15 |
| 1. AL = alignment load, which is less than or equal to 0.05 VTL.
2. Soil nail movement shall be measured after each load increment has been achieved and at each time step.
3. Maintain the load during the creep test within 2 percent of the intended load by use of the load cell.
4. The Engineer may allow loading to failure to determine nominal soil conditions.
5. Permanent soil nail movement shall also be recorded
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**504.16 Proof Testing Of Production Soil Nails.** Successful proof testing shall be performed on 5 percent of the production soil nails in each soil nail row or a minimum of 1 per row. Verification tests shall not be included in the 5 percent; except that the Engineer may allow the verification tests to be included based on the plans and site conditions. The Engineer will determine the locations and number of proof tests prior to soil nail installation in each row unless otherwise shown on the plans. Production proof test soil nails shall have both bonded and temporary unbonded lengths. Fully grouted test soil nails shall not be proof tested. The Contractor shall maintain the stability of the hole for the temporary unbonded test length for subsequent grouting. If the unbonded test length of production proof test soil nails cannot be satisfactorily grouted subsequent to testing, the proof test soil nail shall become sacrificial and shall be replaced with an additional production soil nail installed at the Contractor's expense. The temporary unbonded length of the test soil nail shall be at least 3 feet as measured from the back of the bearing plate to the top of the grout.

Proof tests shall be conducted according to the loading schedule of Table 504-2. Unless the soil is susceptible to creep per subsection 504.15, each load increment shall be held until readings are stable as defined by three readings within 0.005 inches taken one per minute over three minutes. The Contractor shall record soil nail movements at each load increment and the time intervals shown in the table for each load step. Creep tests shall be performed at 1.00 PTL. The alignment load (AL) shall be the minimum load required to align the testing apparatus and shall not exceed 5 percent of the PTL. Set dial gauges to “zero” after applying the alignment load. Following application of the maximum load, reduce the load to the alignment load and record the permanent set.

The creep period shall start as soon as the maximum test load (1.0 PTL) is applied and the soil nail movement shall be measured and recorded at 1 minute, 2, 3, 5, 6, and 10 minutes. Where the soil nail movement between 1 minute and 10 minutes exceeds 0.04 inch, the maximum test load shall be maintained for an additional 50 minutes and movements recorded at 20 minutes, 30, 50, and 60 minutes. All load increments shall be maintained within 5 percent of the intended load.

The bonded length of the soil nail during verification tests, LB PT, shall be:

1. For Grade 75 and other mild steel in accordance with ASTM A615, the maximum bond length (LB PTmax), is defined as:

$$L\_{B PTmax} = \frac{A\_{t}∙f\_{y}∙C\_{RTY}}{r\_{PO}∙0.75}$$

1. For Grade 150 and other high-strength steel in accordance with ASTM A722, the maximum bond length (LB PT max), is defined as:

$$L\_{B PTmax} = \frac{A\_{t}∙f\_{u}∙C\_{RTU}}{r\_{PO}∙0.75}$$

1. Select LB PT to be 10 ft or LB PTmax, whichever is smaller, to avoid tensile breakage.
2. Production proof test soil nails that are shorter than 13 feet may be tested with less than the minimum 10 feet bond length. The maximum load in the proof test (PTL) is calculated as PTL = LB PT × rPO × 0.75

**Table 504-2**

**PROOF TEST LOADING SCHEDULE**

|  |  |
| --- | --- |
| **Load** | **Hold Time (minutes)2** |
| AL1 | 1 |
| 0.17 PTL | Until Movement Stabilizes3 |
| 0.33 PTL | Until Movement Stabilizes |
| 0.50 PTL | Until Movement Stabilizes |
| 0.67 PTL | Until Movement Stabilizes |
| 0.83 PTL | Until Movement Stabilizes |
| 1.0 PTL (Creep Test)4 | 10 (recorded at 1, 2, 4, 5, 6, and 10) |
| AL | 1 |
| Notes: 1. AL = alignment load, which is less than or equal to 0.05 PTL.
2. Times are measured after the target load has been achieved in each increment.
3. If the soils reinforced with soil nails are relatively susceptible to deformation of creep, it is recommended to hold each load increment for 10 minutes and to record the soil nail movement at 1, 2, 5, and 10 minutes.
4. If the soil nail movement measured between 1 and 10 minutes exceeds 0.04 in., PTL must be maintained for 50 additional minutes and movements must be recorded at 20, 30, 50, and 60 minutes. The permanent soil movement must also be recorded.
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**504.17 Test Soil Nail Acceptance Criteria.** A test soil nail shall be considered acceptable when the following criteria are met.

1. *Verification testing*. The following criteria shall be met for acceptance of the soil nail:
2. Pullout shall not occur at loads less than 1.00 VTL.
3. The total movement (ΔVTL) measured at VTL shall exceed 80 percent of the theoretical elastic elongation of the unbonded length (LUB), as defined by:

$$∆\_{VTL}>0.8\frac{VTL∙L\_{UB}}{E∙A\_{t}}$$

where E = Young’s modulus of steel (29,000 ksi).

1. The creep movement between the 1 and 10 minute readings at 0.75 VTL shall be less than 0.04 in.
2. The creep movement between the 6 and 60 minute readings at 0.75 VTL shall be less than 0.08 in.
3. The creep rate shall be linear or decreasing throughout the creep test load-hold period.
4. *Proof* *testing*. The following criteria shall be met to acceptance of the soil nail:
5. No pullout occurs.
6. The total soil nail movement (ΔPTL) measured at PTL shall be greater than 80 percent of the theoretical elastic elongation of the unbonded length, as defined by:

$$∆\_{PTL}>0.8\frac{PTL∙L\_{UB}}{E∙A\_{t}}$$

1. The creep movement shall be less than 0.04 in. between the 1 and 10 minute readings.
2. If this movement is exceeded, PTL shall be maintained for an additional 50 minutes with readings recorded at 20, 30, 50, and 60 minutes.
3. If the creep test is extended, the creep movement between the 6 and 60 minute readings shall be less than 0.08 in.
	1. **Test Soil Nail Rejection.** If a test soil nail does not satisfy the acceptance criterion in subsection 504.17:
4. *Verification test soil nails*. The Engineer will evaluate the results of each verification test. The Contractor shall propose and provide plans and calculations for alternative methods for review and acceptance by the Engineer and shall install replacement verification test soil nails. Replacement test soil nails shall be installed and tested at the Contractor's expense. The production soil nails shall be installed using the same installation procedures (drill equipment, drill tooling, drill hole diameter, grouting, etc.) used to provide successful verification tests at no additional cost to the Department.
5. *Proof test soil nails*. The Engineer may require the Contractor to replace some or all of the installed production soil nails between a failed proof test soil nail and the adjacent passing proof test soil nail. Alternatively, the Engineer may require the installation and testing of additional proof test soil nails to verify that adjacent previously installed production soil nails have sufficient load carrying capacity. Installation and testing of additional proof test soil nails or installation of additional or modified soil nails as a result of proof test soil nail failures shall be at the Contractor's expense.

**504.19 Wall Drainage Network.** All elements of the wall drainage network shall be installed and secured as shown on the plans. The drainage network shall consist of installing geocomposite strip drains, PVC connection pipes, wall footing drains, and weepholes as shown on the plans. Exclusive of the wall footing drains, all elements of the drainage network in the current lift shall be installed prior to shotcreting.

(a) *Geocomposite Strip Drains.* Geocomposite strip drains shall be centered between the columns of soil nails as shown on the Plans. The strip drains shall be at least 12 inches wide and placed with the geotextile side against the ground. The strips shall be secured to the excavation face and shotcrete shall be prevented from contaminating the geotextile. Strip drains shall be vertically continuous. Splices shall be made with a 12 inch minimum overlap such that the flow of water is not impeded. Drain plate and connector pipe shall be installed at the base of each strip as shown on the plans. Damage to the geocomposite strip drain which may interrupt the flow of water shall be repaired.

(b) *Underdrains.* Underdrains shall collect groundwater from the drainage network and be installed at the bottom of each wall as shown on the plans. The drainage geotextile shall envelope the footing drain aggregate and pipe and conform to the dimensions of the trench. The drainage geotextile shall overlap on top of the drainage aggregate as shown on the plans. Damaged or defective drainage geotextile shall be repaired or replaced.

**504.20 Initial Shotcrete Facing.** The initial shotcrete facing shall be installed in accordance with Section 641. Membrane curing compound shall not be used. Maturity meters shall be used to monitor all shotcrete in accordance with subsection 641.05.

(a) *Initial Face Finish.* Shotcrete finish shall be either an undisturbed gun finish as applied from the nozzle or a rod, broom, wood float, rubber float, steel trowel or rough screeded finish as shown on the Plans.

(b) *Attachment of Soil Nail Head Bearing Plate and Nut.* Bearing plate, washers, and nut shall be attached to each soil nail head as shown on the plans. While the initial shotcrete facing is still plastic and before its initial set, the plate shall be uniformly seated on the shotcrete by hand-wrench tightening the nut. Where uniform contact between the plate and the shotcrete cannot be provided, the plate shall be set in a bed of grout. After grout has set for 24 hours, the nut shall be hand-wrench tightened. Bearing plates and headed studs shall be located within the tolerances shown on the Plans.

1. *Shotcrete Facing Tolerances.* Construction tolerances for the shotcrete facing from plan location and plan dimensions shall be as shown in Table 504-3.

**Table 504-3**

**INITIAL SHOTCRETE FACING TOLERANCES**

|  |  |
| --- | --- |
| **Item** | **Tolerance** |
| Horizontal location of welded wire mesh, reinforcing bars, and headed studs measured horizontally from wall face | 3/8 in. |
| Location of headed-studs on bearing plate | 1/4 in. |
| Spacing between reinforcing bars | 1 in. |
| Reinforcing lap length | 1 in. |
| Thickness of shotcrete, if troweled or screeded | 9/16 in. [approximation of 0.6 in.] |
| Thickness of shotcrete, if left as shot | 1-1/8 in. [approximation of 1.2 in.] |
| Planeness of finish face surface, gap under 10-ft straightedge, if troweled or screeded | 9/16 in. [approximation of 0.6 in.] |
| Planeness of finish face surface, gap under 10-ft straightedge, if left as shot | 1-1/8 in. [approximation of 1.2 in.] |
| Soil nail head bearing plate deviation from parallel to wall face | * + 1. egrees
 |

**504.21 Forms and Falsework.** Forms and falsework shall conform to subsections 601.09 and 601.11 respectively.

**504.22 Reinforcing Steel.**  Reinforcing steel shall be installed in accordance with this specification and Section 602.

**504.23 Structural Concrete.** Structural concrete shall be placed in accordance with this specification and Section 601.

**504.24 Acceptance.**  Material for the soil nail retaining wall will be accepted based on the manufacturer production certification or from production records. Construction of the soil nail retaining wall will be accepted based on survey, visual inspection, and the relevant production testing records.

**METHOD OF MEASUREMENT**

**504.25** Soil nail walls will be measured by the quantities for the five major components of the wall: soil nail, initial shotcrete facing, verification testing, excavation and underdrain.

Soil nail will be measured by the linear foot of nail installed and accepted.

Verification testing will be measured by the number of verification tests performed.

**BASIS OF PAYMENT**

**504.26** The accepted quantities, measured as provided above, will be paid for at the contract unit price for the pay items listed below that are shown on the bid schedule. Payment will be made under:

Payment will be made under:

**Pay Item Pay Unit**Soil Nail Linear Foot
Verification Testing Each

Payment for Soil Nail Wall will be full compensation for all work and materials required to complete soil nail, initial shotcrete facing, verification testing, excavation and underdrain. This work shall include but is not limited to soil nails, proof testing, drilling, grouting, bearing plates, end hardware (nuts, washers, couplers), certificates of compliance, shotcrete steel, mesh reinforcement, and incidentals necessary to acceptably fabricate and construct the soil nail walls exclusive of any facing items that may be tabulated on the plans.

All excavation work required to construct the soil nail wall and the initial shotcrete facing to the lines and grades indicated on the plans will be measured and paid for in accordance with Section 203. Additional earthwork outside of excavation for the wall installation and backfilling prior to or post wall construction will not be measured and paid for separately, but shall be included in the work.

Underdrain will be measured and paid for in accordance with Section 605.

Initial Shotcrete Facing will be measured and paid for in accordance with Section 641.

Incidental shotcrete required for over-break will be measured and paid for in accordance with Section 641 under Pay Item Shotcrete.

Subsection 641.07 shall include the following:

Initial Shotcrete Facing for soil nail wall will be measured by the actual square feet of shotcrete that is applied to the depth shown on the plans. Square feet of wall will be determined using the height measured at 20 foot maximum intervals along the wall layout line.

Subsection 641.09 shall include the following:

**Pay Item Pay Unit**Initial Shotcrete Facing Square Foot