

REVIEW OF NEW SPECIFICATION OR SPECIFICATION CHANGE

504-13

Specification Section No.: 504

Item: Soil Nail Wall

Originating Office: MAC

By: David Thomas

Date Sent For Review: 09.20.16

Date Comments Due: 10.18.16

**Submit response to: STANDARDS AND SPECIFICATIONS UNIT, DIVISION OF PROJECT SUPPORT
4TH FLOOR, CDOT HEADQUARTERS**

Vote Y/N	Concurrent Reviews – Others Commenting	
	Spec Committee Members:	✓
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	PDAC	
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The attached Draft Specification is submitted for your review and comments. If not returned by Date Comments Due, the draft specification will be considered to be approved unless the Standards and Specifications Unit of the Project Development Branch [(303) 757-9474, (303) 757-9402] is advised otherwise.

REMARKS:

If these changes are approved, our unit will issue these in a new Standard Special Provision.

REVIEWER COMMENTS:

() Approved () Disapproved () Modified

If disapproved or modified, give reason why and show any modifications on the attached draft copy:

Name/Signature

Date

COLORADO DEPARTMENT OF TRANSPORTATION SUBMITTAL OF NEW SPECIFICATION OR SPECIFICATION CHANGE		Log No. (Assigned by Standards and Specifications Unit)
TO: Standards and Specifications Unit, Project Development, Suite 290	FROM: Materials Advisory Committee (Region, Branch or Technical Committee)	
SPECIFICATION SECTION NO. 504 or as determined by the Committee	ITEM Soil Nail Wall	Priority Routine <input checked="" type="checkbox"/> Fast <input type="checkbox"/>
Reason for this new or changed specification: There is no standard specification for soil nail walls. This will allow CDOT to be up to date with current regulations published in 2015 by FHWA. The changes were developed under a Materials Advisory Committee (MAC) Task Force TF 2015-03 involving the Colorado Contractors Association. The specification changes were approve by the MAC.		
New or Revised Specification: See Attached.		
NOTE: See Procedural Directive 513.1 for a description of appropriate specification development procedures.		

REVISION OF SECTION 504
SOIL NAIL WALL

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

DESCRIPTION

504.01 This work consists of constructing a permanent soil nailed wall (also referred to as ground nail wall) as specified herein, as shown on the plans. Temporary soil nail walls and the final facing are not covered in this specification. The work includes:

- (1) Excavating staged lifts in accordance with the plans and approved submittals.
- (2) Drilling soil nail holes to the diameter and length required to develop the specified capacity as shown on the plans.
- (3) Installing soil nails including placement and grouting.
- (4) Performing soil nail testing and providing test results to the Engineer.
- (5) Providing and installing the specified drainage features.
- (6) Providing and installing bearing plates, washers, nuts, couplers, and other required miscellaneous materials.
- (7) Constructing the initial shotcrete face.

MATERIALS

504.02 Materials shall meet the following requirements:

- (1) Concrete shall be Class D, conforming to the requirements of Section 601.
- (2) Reinforcing Steel shall conform to the requirements of Section 602.
- (3) Shotcrete shall conform to the requirements of Section 641.
- (4) Forms and falsework shall conform to the requirements of subsections 601.09 and 601.11.
- (5) Geocomposite strip drains shall comply with Section 712.12.
- (6) Underdrains and pipes shall comply with Sections 712.11 and 712.13.

504.03 Soil Nails

- (a) *Solid Bar Soil Nail.* Bars shall conform to AASHTO M31 for Grade 75 or ASTM A 722 for Grade 150. Bars shall be deformed, continuous without splices or welds, new, straight, undamaged, or 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.
- (b) *Bar Coupler.* Bar couplers shall develop the full ultimate tensile strength of the bar as certified by the manufacturer.

- (c) *Fusion Bonded Epoxy Coating.* Epoxy coating 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.
- (d) *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.
- (e) *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 insertion along the full length of the drill hole.
 - (4) Sized to allow grout to freely flow up the drill hole.
- (f) *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 AASHTO T106/ASTM C109. If sand is used in the grout mixture, it shall meet the requirements of AASHTO M6/ASTM C33. The water/cement ratio and specific gravity can be used as a primary quality control of the neat cement grout mix if 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. Additional neat cement grout cubes may still be molded and tested periodically as needed as verification of grout compressive strength as determined by the Engineer.
- (g) *Fine Aggregate.* Fine aggregate shall conform to AASHTO M6.
- (h) *Portland Cement.* Portland Cement shall conform to AASHTO M85, Type I, II, III, or V and shall be the product of one manufacturer. If the brand or type of cement is changed during the project, additional grout mix tests shall be conducted to ensure consistency of quality and performance in situ. The type of cement used for shotcrete and grout shall be based on Table 601-2 based on the highest measured water-soluble sulfate content of the retained soil.
- (i) *Admixtures.* Admixtures shall conform to AASHTO M194. 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.
- (j) *Film Protection.* Polyethylene film for moisture loss control shall conform to AASHTO M171.

504.04 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 consist of headed studs and conform to requirements of Section 509.12.

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

504.06 Initial Shotcrete Facing. The Contractor shall submit for review and acceptance all materials, methods, and control procedures for this work.

CONSTRUCTION REQUIREMENTS

504.07 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.

504.08 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 approved by the Engineer.

- (a) *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, number of nails, scheduled completion date, and actual completion date for the project.
- (b) *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 of the Engineer. The Engineer will approve or reject 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 approved personnel during construction. If work is suspended due to the substitution of unqualified personnel, 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.
- (c) *Construction Plan.* At least 14 days before starting soil nail work, the soil nailing Contractor shall submit a Construction Plan to the Engineer that includes the following:
 - (1) 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, soil nail testing, and shotcrete placement.
 - (2) 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 variation of these along the wall alignment.
 - (3) 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.
 - (4) Soil nail grout placement procedures and equipment.
 - (5) Shotcrete materials and methods including methods to address soil fall out, perched water, and anti-

washout as needed based on review of the Geotechnical Report.

- (6) All materials, methods, and control procedures for the initial shotcrete facing for review and acceptance for this work.
- (7) Soil nail testing methods and equipment setup.
- (8) 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.
- (9) Certificates of Compliance for:
 - a. The soil nail yield or ultimate tensile strength.
 - b. Soil nail bar steel type.
 - c. Portland cement used for grout
 - d. Soil nail centralizers.
 - e. Bearing plates, washers, nuts, and couplers.
 - f. Corrosion protection.
 - g. Geocomposite strip drain and underdrain material.

The Engineer will approve or reject the soil nailing Contractor's Construction Plan within 10 working days after the submission. Approval of the Construction Plan does not relieve the Contractor of responsibility for the successful completion of the work.

504.09 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, traffic control, and other nearby structures.

504.10 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 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.

504.11 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 with the soil nail wall design professional engineer licensed in Colorado for personnel 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 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 the Geotechnical Report for additional information concerning the ground conditions that are anticipated during excavation.

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. 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 in the current lift. Soil nail grout and shotcrete shall have a working strength of 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. The Contractor shall determine the method of removal of face protrusions, including method to safely secure remnant pieces left behind the excavation face, and method for 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 excavation operation shall be backfilled with shotcrete, concrete, or grout.

504.12 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, such as increasing the drill hole diameter or improving the roughness of the drill hole 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 accepted 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).

504.13 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 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 needed modification in wall design and construction. Maintain the temporary unbonded length of proof test soil nails open 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 use of a grout "sock" may be used as approved by the Engineer to prevent the collapse of the drill hole and to reduce grout flow into the highly-permeable soil.

504.14 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 soil nail Designer of Record to review any excavation at the foot of the wall for stability.

SOIL NAIL TESTING

504.15 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 gauge system with the low reading gauge being used for soil nail acceptance. A load cell is required for creep susceptible soils which show one or more of the following properties:

- (1) Fine grained soils
- (2) Organic soils
- (3) Liquid Limit (LL) ≥ 50
- (4) Plasticity Index (PI) ≥ 20
- (5) Undrained Shear Strength (S_u) $\leq 1,000$ psf
- (6) Liquidity Index ≥ 0.2 [$LI=(W-PL)/(LL-PL)$]; (PL) plastic limit and (W) natural water content

The Contractor shall also have calibrated back up gauges and equipment to minimize down time due to testing equipment failure. 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 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.

504.16 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. The bonded length of the soil nail during verification tests (L_{BVT}) shall be:

- (1) For Grade 75 and other mild steel in accordance with ASTM A615, the maximum bond length (L_{BVTmax}), is defined as:

$$L_{BVTmax} = \frac{A_t \cdot f_y \cdot C_{RTY}}{r_{PO}}$$

- (2) For Grade 150 and other high-strength steel in accordance with ASTM A722, the maximum bond length (L_{BVTmax}), is defined as:

$$L_{BVTmax} = \frac{A_t \cdot f_u \cdot C_{RTU}}{r_{PO}}$$

where:

C_{RTY} = reduction coefficient for mild-grade steel = 0.9

C_{RTU} = reduction coefficient for high-strength steel = 0.8

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

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

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

r_{PO} = nominal pullout resistance in kips per foot of test soil nail per plans = $\pi \times q_u \times D_{DH}$

q_u = nominal bond strength in kips per square foot

D_{DH} = drill hole diameter in feet

- (3) If $L_{BVTmax} > 10$ feet, select L_{BVT} to be 10 feet $\leq L_{BVT} \leq L_{BVTmax}$.
- (4) If $L_{BVTmax} < 10$ feet, to avoid tensile breakage, select $L_{BVT} = 10$ feet and increase the test soil nail bar size as needed, and recalculate L_{BVTmax} until $L_{BVTmax} > 10$ ft.
- (5) The maximum (nominal) load during the verification test is defined as the Verification Test Load (VTL) and is calculated as $VTL = L_{BVT} \times r_{PO}$

Verification tests are conducted according to the loading schedule of Table 504-1. Each load increment is held for at least 10 minutes. The Contractor must record soil nail movements at each load increment and the time intervals shown in the table for each load step. Creep tests are 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. 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.

Hold each load increment for at least 10 minutes. Monitor the verification test soil nail for creep at the 0.75 VTL load increment by measuring and recording soil nail movement. Maintain the load during the creep test within 2 percent of the intended load by use of the load cell. The test results shall be presented in a report with cover letter and stamped by a Colorado registered Professional Engineer 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.

Table 504-1
VERIFICATION TEST LOADING SCHEDULE

Load	Hold Time (minutes) ⁽²⁾
AL ⁽¹⁾	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 VTL ⁽⁴⁾	10
AL	1 ⁽⁵⁾

Notes: (1) AL = alignment load, which is less than or equal to 0.05 VTL.

(2) Soil nail movement must 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 must also be recorded.

504.17 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; however, 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. The bonded length of the soil nail during verification tests, $L_{B PT}$, shall be:

- (1) For Grade 75 and other mild steel in accordance with ASTM A615, the maximum bond length ($L_{B PTmax}$), is defined as:

$$L_{B PTmax} = \frac{A_t \cdot f_y \cdot C_{RTY}}{r_{PO} \cdot 0.75}$$

- (2) For Grade 150 and other high-strength steel in accordance with ASTM A722, the maximum bond length ($L_{B PTmax}$), is defined as:

$$L_{B PTmax} = \frac{A_t \cdot f_u \cdot C_{RTU}}{r_{PO} \cdot 0.75}$$

- (3) Select $L_{B PT}$ to be 10 ft or $L_{B PTmax}$, whichever is smaller, to avoid tensile breakage.
- (4) 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) and is calculated as $PTL = L_{B PT} \times \Gamma_{PO} \times 0.75$

Proof tests are conducted according to the loading schedule of Table 504-2. Unless the soil is susceptible to creep per subsection 504.15, each load increment is 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.

**Table 504-2
PROOF TEST LOADING SCHEDULE**

Load	Hold Time (minutes) ⁽²⁾
AL ⁽¹⁾	1

0.17 PTL	Until Movement Stabilizes ⁽³⁾
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.

504.18 Test Soil Nail Acceptance Criteria. A test soil nail shall be considered acceptable when the following criteria are met.

(a) *Verification testing.* The following criteria shall be met for acceptance of the soil nail:

(1) Pullout shall not occur at loads less than 1.00 VTL.

(2) The total movement (Δ_{VTL}) measured at VTL shall exceed 80 percent of the theoretical elastic elongation of the unbonded length (L_{UB}), as defined by:

$$\Delta_{VTL} > 0.8 \frac{VTL \cdot L_{UB}}{E \cdot A_t}$$

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

(3) The creep movement between the 1 and 10 minute readings at 0.75 VTL shall be less than 0.04 in.

(4) The creep movement between the 6 and 60 minute readings at 0.75 VTL shall be less than 0.08 in.

(5) The creep rate shall be linear or decreasing throughout the creep test load-hold period.

(b) *Proof testing.* The following criteria shall be met to acceptance of the soil nail:

(1) No pullout occurs.

(2) The total soil nail movement (Δ_{PTL}) measured at PTL shall be greater than 80 percent of the theoretical elastic elongation of the unbonded length, as defined by:

$$\Delta_{PTL} > 0.8 \frac{PTL \cdot L_{UB}}{E \cdot A_t}$$

(3) The creep movement shall be less than 0.04 in. between the 1 and 10 minute readings.

(4) If this movement is exceeded, PTL shall be maintained for an additional 50 minutes with readings recorded at 20, 30, 50, and 60 minutes.

(5) If the creep test is extended, the creep movement between the 6 and 60 minute readings shall be less than 0.08 in.

504.19 Test Soil Nail Rejection. If a test soil nail does not satisfy the acceptance criterion in Subsection 504.18:

- (a) *Verification test soil nails.* The Engineer will evaluate the results of each verification test. Installation methods that do not satisfy the soil nail testing requirements will be rejected. 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.
- (b) *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.

WALL FACING

504.20 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 drain strips, 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 Drain Strips.* Geocomposite drain strips shall be centered between the columns of soil nails as shown on the Plans. The drain strips 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 prevented from contaminating the geotextile. Drain strips 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 drain strip which may interrupt the flow of water shall be repaired.
- (b) *Footing Drains.* Footing drains shall collect groundwater from the drainage system 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.

504.21 Shotcrete Facing. The initial shotcrete facing and final shotcrete facing (if required) 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.
- (c) *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	10 degrees

504.22 Forms And Falsework. Forms and falsework shall conform to subsections 601.09 and 601.11 respectively.

504.23 Reinforcing Steel. Reinforcing steel shall be installed in accordance with Section 602.

504.24 Structural Concrete. Structural concrete shall be placed in accordance with Section 601.

504.25 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

504.26 Soil nail retaining walls will be calculated and paid by the number of nails by length. Tiered and stepped walls shall be considered separate walls. The final pay quantity will be the design quantity increased or decreased by any changes authorized by the Engineer. Additional earthwork outside of excavation for the wall installation and backfilling prior to or post wall construction is not included. Soil nails must be installed, tested, and accepted to be considered complete.

BASIS OF PAYMENT

504.27 The accepted quantity, measured as provided above, will be paid for at the contract unit price per square foot for the pay item listed below that is shown on the bid schedule. Payment will be made under:

Pay Item	Pay Unit
Soil Nail (10 ft or less)	Each
Soil Nail (greater than 10 ft to 15 ft)	Each
Soil Nail (greater than 15 ft to 20 ft)	Each

Soil Nail (greater than 20 ft to 25 ft)	Each
Soil Nail (greater than 25 ft to 30 ft)	Each
Soil Nail (greater than 30 ft)	Each
Initial Facing	Square foot
Verification Testing	Each

Payment for Soil Nail Wall will be full compensation for all work and materials required to complete the soil nail walls. This work shall include but is not limited to soil nails, soil nail proof testing, drilling, grouting, bearing plates, end hardware (nuts, washers, couplers), survey, manufacturer's certificates of compliance, corrosion protection, geocomposite strip drains, 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, including structure excavation and rock excavation required to construct the soil nail wall and initial shotcrete to the lines and grades indicated on the plans will be paid for in accordance with Section 203.

Shotcrete, incidental shotcrete to fill overbreak, incidental flowfill to fill overbreak, and all shotcrete steel or mesh reinforcement delineated in the plans will be paid for in accordance with Section 641 Shotcrete.