

SOIL NAIL RETAINING WALLS

(2-16-10)

1.0 GENERAL

A soil nail is defined as a steel bar grouted in a drilled hole inclined at an angle below horizontal. A soil nail retaining wall consists of soil nails spaced at a regular pattern and connected to a cast-in-place reinforced concrete face with nail heads embedded in the concrete. Shotcrete is used for temporary support of the excavation during construction. Design and construct soil nail retaining walls based on actual elevations and dimensions in accordance with the contract and accepted submittals. For this provision, “soil nail wall” refers to a soil nail retaining wall and “Soil Nail Wall Contractor” refers to the contractor installing soil nails and applying shotcrete. Also, “concrete facing” refers to a cast-in-place reinforced concrete face.

2.0 SUBMITTALS

Three submittals are required. These submittals include (1) Soil Nail Wall Contractor personnel and experience, (2) soil nail wall design and (3) soil nail wall construction plan. Provide 11 hard copies of working drawings and 3 hard copies of design calculations for the soil nail wall design submittal and 4 hard copies of the remaining submittals. Also, submit an electronic copy (PDF on CD or DVD) of each submittal. Allow 10 calendar days for the review of the Soil Nail Wall Contractor personnel and experience submittal. After the personnel and experience submittal is accepted, submit the remaining submittals at least 30 calendar days before starting soil nail wall construction. Do not begin soil nail wall construction including preconstruction test panels or sacrificial soil nails for verification tests until the construction plan is accepted.

A. Soil Nail Wall Contractor Personnel and Experience Submittal

Use a Soil Nail Wall Contractor prequalified by the NCDOT Contractual Services Unit for anchored retaining walls work (work code 3020). Submit documentation that the Soil Nail Wall Contractor has successfully completed at least 5 soil nail wall projects and 500 soil nails within the last 3 years with wall heights similar to those for this project and an exposed face area for all 5 walls of at least 10,000 ft² (930 m²). Documentation should include the General Contractor and Owner’s name and current contact information with descriptions of each past project.

Provide verification of employment with the Soil Nail Wall Contractor for the Superintendent, Project Manager and Nozzlemen assigned to this project. Submit documentation that the Superintendent and Project Manager each have a minimum of 5 years experience in soil nail wall construction with past projects of scope and complexity similar to that anticipated for this project. Documentation should include resumes, references, certifications, project lists, experience descriptions and details, etc. Submit documentation that each Nozzelman is certified as an ACI Shotcrete Nozzelman by the American Concrete Institute (ACI) in accordance with ACI Certification Publication CP-60. Nozzlemen should be certified in either dry or wet mix vertical based on how the shotcrete will be applied for this project. Perform work

with the personnel submitted and accepted. If personnel changes are required during construction, suspend soil nail wall construction until replacement personnel are submitted and accepted.

A Design Engineer is required to design soil nail walls. Submit documentation that the Design Engineer is registered as a Professional Engineer in North Carolina and has at least 5 years experience in designing soil nail walls with heights and in subsurface conditions similar to those for this project. Documentation should include resumes, references, certifications, project lists, experience descriptions and details, etc. The Design Engineer may also act as the Project Manager provided the Design Engineer meets the Project Manager requirements above.

B. Soil Nail Wall Design Submittal

The Retaining Wall Plans show plan views, typical sections, details, notes and elevation or profile views (wall envelope) for each soil nail wall. When noted on plans and before beginning soil nail wall design, survey existing ground elevations shown on the plans and submit a revised wall envelope for review and acceptance. Use the accepted revised wall envelope for design.

Design soil nail walls in accordance with the plans and the allowable stress design method in the *FHWA Geotechnical Engineering Circular No. 7 "Soil Nail Walls"* (Publication No. FHWA-IF-03-017) unless otherwise required.

Do not extend soil nails beyond right-of-way or easement lines. If existing or future obstructions such as foundations, guardrail posts, pavements, pipes, inlets or utilities will interfere with soil nails, maintain a minimum clearance of 6" (150 mm) between the obstruction and the nails. Use soil nails meeting the following requirements unless otherwise approved.

- Minimum vertical and horizontal spacing of 3 ft (1 m)
- Minimum inclination of 12 degrees below horizontal
- Clearance between the end of the bar and the hole of 6" (150 mm)
- Diameter ranging from 6 to 10 inches (150 to 250 mm)

Four inch (100 mm) diameter soil nails may be approved for drill holes in rock at the discretion of the Engineer.

Geocomposite drain strips are required between the shotcrete and excavation face. Space drain strips to miss nail heads and on 10 ft (3 m) centers, maximum. Connect drain strips to leveling pads. Extend continuous drains along base of concrete facing in front of leveling pads. Provide drains meeting the requirements of an aggregate shoulder drain in accordance with Roadway Standard Drawing No. 816.02.

For temporary facing, use a minimum shotcrete thickness of 4" (100 mm) and reinforce shotcrete with #4 (#13) whaler bars around each nail head. Two reinforcing bars (one on each side of the nail head) in both the vertical and horizontal directions for a total of 4 whaler bars per soil nail are required.

For permanent facing, use a minimum cast-in-place reinforced concrete thickness of 8” (200 mm). Extend concrete facing a minimum of 6” (150 mm) above where finished grade intersects the back of soil nail walls unless required otherwise on the plans. When barriers are required above soil nail walls, use concrete barrier rails with moment slabs in accordance with the plans.

Use 6 inch (150 mm) thick aggregate leveling pads beneath concrete facing. Unless required otherwise on the plans, embed top of leveling pads a minimum of 1 ft (0.3 m) below where finished grade intersects the front face of soil nail walls.

Submit working drawings and design calculations including unit grout/ground bond strengths for review and acceptance in accordance with Article 105-2 of the *Standard Specifications*. Submit working drawings showing plan views, wall profiles with soil nail locations including known test nail locations, typical sections and soil nail, drainage, shotcrete, leveling pad, concrete facing and reinforcing details. If necessary, include details on working drawings for concrete barrier rails with moment slabs and obstructions interfering with soil nails or extending through walls. Submit design calculations for each wall section with different surcharge loads, geometry or material parameters. A minimum of one analysis is required for each wall section with different soil nail lengths. When using a software program for design, provide a hand calculation verifying the analysis of the section with the longest soil nails. Have soil nail walls designed, detailed and sealed by the Design Engineer.

C. Soil Nail Wall Construction Plan Submittal

Submit detailed project specific information including the following.

1. Excavation methods and equipment.
2. List and sizes of proposed drilling rigs and tools, tremies and grouting equipment.
3. Sequence and step-by-step description of soil nail wall construction including details of excavations, drilling and grouting methods, soil nail and wall drainage system installation and facing construction.
4. Shotcrete equipment and placement details including mix process, test panels, thickness measuring gauges and application methods.
5. Soil nail testing details, procedures and plan sealed by a Professional Engineer registered in North Carolina with calibration certificates dated within 90 calendar days of the submittal date in accordance with Section 7.0.
6. Examples of construction and test nail records to be provided in accordance with Sections 6.0 and 7.0, Item F, respectively.
7. Grout mix design including laboratory test results in accordance with the *Grout for Structures* provision and acceptable ranges for grout flow and density.

8. Shotcrete mix design in accordance with the *Shotcrete* provision.
9. Other information shown on the plans or requested by the Engineer.

If alternate installation and testing procedures are proposed or necessary, a revised construction plan submittal may be required. If the work deviates from the accepted submittal without prior approval, the Engineer may suspend soil nail wall construction until a revised plan is submitted and accepted.

3.0 MATERIALS

Provide Type 3 Manufacturer's Certifications in accordance with Article 106-3 of the *Standard Specifications* for soil nail and wall drainage materials. Store steel materials on blocking a minimum of 12" (300 mm) above the ground and protect it at all times from damage; and when placing in the work make sure it is free from dirt, dust, loose mill scale, loose rust, paint, oil or other foreign materials. Load, transport, unload and store soil nail wall materials such that they are kept clean and free of damage. Do not crack, fracture or otherwise damage grout inside sheathing of shop grouted encapsulated soil nails. Damaged or bent materials will be rejected.

A. Soil Nails

A soil nail consists of a grouted steel bar with corrosion protection and a nail head assembly. Use epoxy coated or encapsulated deformed steel bars meeting the requirements of AASHTO M275 or M31, Grade 60 or 75 (420 or 520). Splice bars in accordance with Article 1070-10 of the *Standard Specifications*.

For epoxy coated bars, provide epoxy coated reinforcing steel meeting the requirements of Article 1070-8 of the *Standard Specifications*.

For encapsulated bars, use unperforated corrugated high-density polyethylene (HDPE) sheathing a minimum of 0.04" (1 mm) thick meeting the requirements of AASHTO M252. Provide at least 0.4" (10 mm) of grout cover between the bar and sheathing and at least 0.8" (20 mm) of grout cover between the sheathing and drill hole wall.

Fabricate centralizers from schedule 40 polyvinyl chloride (PVC) plastic pipe or tube, steel or other material not detrimental to steel bars (no wood). Size centralizers to position the bar within 1 inch (25 mm) of the drill hole center and allow a tremie to be inserted to the bottom of the hole. Use centralizers that do not interfere with grout placement or flow around bars. For encapsulated bars, centralizers are required both inside and outside of encapsulation.

Use grout in accordance with the contract.

Nail head assemblies consist of steel bearing plates, washers, nuts and shear studs. Provide steel bearing plates meeting the requirements of ASTM A36 and washers and hex nuts in accordance with the bar manufacturer's recommendations. Provide welded stud shear connectors in accordance with Article 1072-8 of the *Standard Specifications*.

B. Wall Drainage Systems

Wall drainage systems consist of drain strips, drains and outlet components. Provide minimum average roll values (MARV) as defined by ASTM D4439 for core properties of drain strips. For testing drain strips, a lot is defined as a single day's production. Identify, store and handle drain strips in accordance with ASTM D4873. Drain strips with defects, flaws, deterioration or damage will be rejected. Do not leave drain strips uncovered for more than 7 days.

Use at least 12 inch (300 mm) wide prefabricated geocomposite drain strips consisting of a non-woven polypropylene geotextile bonded to one side of an HDPE or polystyrene drainage core, e.g., sheet drain. Provide drain strips with cores meeting the following requirements.

Core Property	Test Method	Requirement (MARV)
Thickness	ASTM D5199	¼ - ½ inch (6 – 13 mm)
Compressive Strength	ASTM D1621	40 psi (276 kPa) min
Flow Rate (with a gradient of 1.0)	ASTM D4716	5 gpm (1 l/s) min*

* per ft (m) of width tested

Use drain and outlet materials meeting the requirements of Section 816 of the *Standard Specifications*.

C. Shotcrete

Use shotcrete in accordance with the contract.

D. Reinforcing Steel

Use deformed steel bar reinforcement and welded wire fabric meeting the requirements of reinforcing steel in accordance with Section 1070 of the *Standard Specifications*.

E. Leveling Pads

Use Class VI Select Material in accordance with Section 1016 of the *Standard Specifications* for aggregate leveling pads.

F. Concrete Facing and Concrete Barrier Rails with Moment Slabs

Provide concrete facing and concrete barrier rails with moment slabs meeting the requirements of Section 1000 of the *Standard Specifications*. Use Class A Concrete for concrete facing and moment slabs and Class AA Concrete for concrete barrier rails in accordance with Article 1000-4 of the *Standard Specifications*.

G. Joint Materials

Use joint materials in accordance with Section 1028 of the *Standard Specifications*.

4.0 SOIL NAIL WALL PRECONSTRUCTION MEETING

Before starting soil nail wall construction, conduct a preconstruction meeting to discuss the construction, inspection and testing of the soil nail walls. Schedule this meeting after all soil nail wall submittals have been accepted. The Resident or Bridge Maintenance Engineer, Bridge Construction Engineer, Geotechnical Operations Engineer, Contractor and Soil Nail Wall Contractor Superintendent, Project Manager and Design Engineer will attend this preconstruction meeting.

5.0 CONSTRUCTION METHODS

Control drainage during construction in the vicinity of soil nail walls. Direct run off away from soil nail walls and areas above and behind walls.

Perform necessary clearing and grubbing in accordance with Section 200 of the *Standard Specifications*. Notify the Engineer before blasting in the vicinity of soil nail walls. Perform blasting in accordance with the contract. Install foundations located behind soil nail walls and within a horizontal distance equal to the longest soil nail length before beginning soil nail wall construction.

Do not excavate behind soil nail walls. If overexcavation occurs, repair walls at no additional cost to the Department with a method proposed by the Contractor and accepted by the Engineer. A revised soil nail wall construction plan may be required.

Perform any welding in accordance with the contract. At the Contractor's option, welding may be performed in the field in lieu of employing an American Institute of Steel Construction (AISC) certified fabricator in accordance with Subarticle 1072-1(A) of the *Standard Specifications*. For field welding, use welders certified as a bridge welder in accordance with the NCDOT Field Welder Certification Program.

Use equipment and methods reviewed and accepted in the construction plan or approved by the Engineer. Inform the Engineer of any deviations from the accepted plan.

A. Excavation

Construct soil nail walls from the top down by removing material in front of walls and providing an excavation face to receive shotcrete meeting the following tolerances.

- Within 2" (50 mm) of the location shown on the plans
- Within 2% of vertical
- No negative batter (excavation face leaning forward)

Excavate in accordance with the accepted submittals and in staged horizontal lifts with heights not to exceed the vertical soil nail spacing. Do not excavate more than 3 ft (1 m) below where soil nails will be installed. Remove any cobbles, boulders, rubble or debris that will protrude more than 2" (50 mm) into the required shotcrete thickness. Rocky ground such as colluvium, boulder fills and weathered rock may be difficult to excavate without leaving voids.

Apply shotcrete to the excavation face within 24 hours of excavating the lift unless approved otherwise by the Engineer. The application of shotcrete may be delayed if it can be demonstrated that the delay will not adversely affect the excavation face stability. If the excavation face will be exposed for more than 24 hours, use polyethylene sheets anchored at the top and bottom of the lift to protect the face from changes in moisture content.

If the excavation face becomes unstable at any time, suspend soil nail wall construction and temporarily stabilize the face by immediately placing an earth berm against the unstable face. Soil nail wall construction may not proceed until remedial measures are proposed by the Contractor and accepted by the Engineer. A revised soil nail wall construction plan submittal may be required.

Do not excavate the next lift until the soil nail installations, shotcrete application, nail head assemblies and soil nail testing for the preceding lift are complete and the soil nails for the preceding lift are accepted by the Engineer. Also, do not excavate the next lift until the grout and shotcrete for the preceding lift have cured at least 3 days and 1 day, respectively.

B. Soil Nail Installation

Install soil nails in the same way as acceptable verification test nails. Drill and grout soil nails the same day and do not leave drill holes open overnight.

Control drilling and grouting to prevent excessive ground movements, damaging structures and pavements and fracturing rock and soil formations. If ground heave or subsidence occurs, suspend soil nail wall construction and take action to minimize movement. If structures or pavements are damaged, suspend wall construction and repair structures and pavements at no additional cost to the Department with a method proposed by the Contractor and accepted by the Engineer. The Engineer may require a revised soil nail wall construction plan when corrective action is necessary.

1. Drilling

Use drilling rigs capable of drilling through whatever materials are encountered to the dimensions and orientations required for the soil nail wall design. Drill straight and clean holes at locations shown in the accepted submittals. Drill hole locations and inclinations are required to be within 6" (150 mm) and 2 degrees, respectively, of that shown in the accepted submittals unless approved otherwise by the Engineer.

Stabilize drill holes with temporary casings if unstable, caving or sloughing material is anticipated or encountered. Do not use drilling fluids to stabilize drill holes or remove cuttings.

2. Soil Nail Bars

Use centralizers to center steel bars in drill holes. Securely attach centralizers at maximum 8 ft (2.4 m) intervals along bars. Attach uppermost and lowermost centralizers 18" (450 mm) from the top and bottom of drill holes.

Before placing soil nail bars, allow the Engineer to check location, orientation and cleanliness of drill holes. Provide steel bars as shown in the accepted submittals and insert bars without difficulty or forcing insertion. Do not vibrate or drive soil nail bars. If a bar can not be completely inserted easily, remove the bar and clean or redrill the hole.

3. Grouting

Remove oil, rust inhibitors, residual drilling fluids and similar foreign materials from holding tanks/hoppers, stirring devices, pumps, lines, tremie pipes and all other equipment in contact with grout before use.

Place grout with a tremie in accordance with the contract and accepted submittals. Inject grout at the lowest point of drill holes through a tremie pipe, e.g., grout tube, casing, hollow-stem auger or drill rod, in one continuous operation. Fill drill holes progressively from the bottom to top and withdraw tremie at a slow even rate as the hole is filled to prevent voids in the grout. Extend tremie pipe into grout a minimum of 5 ft (1.5 m) at all times except when grout is initially placed in a drill hole.

Provide grout free of segregation, intrusions, contamination, structural damage or inadequate consolidation (honeycombing). Cold joints in grout are not allowed except for soil nails that are tested. Extract temporary casings as grout is placed. Monitor and record grout volumes during placement.

4. Nail Heads

After shotcreting, attach nail head assemblies as shown in the accepted submittals. Before shotcrete reaches initial set, seat plates and tighten nuts so plates contact shotcrete uniformly. If uniform contact is not possible, install nail head assemblies on a mortar pad to provide even bearing against shotcrete.

C. Wall Drainage Systems

Install wall drainage systems as shown in the accepted submittals. Before shotcreting, place and secure geocomposite drain strips with the geotextile side against the excavation face. For highly irregular excavation faces, the Engineer may allow placing drain strips after shotcreting with weep holes through the shotcrete. Ensure that drain strips continuously contact the excavation face and allow for full flow the entire height of the wall. Discontinuous drain strips are not allowed. If splices are needed, overlap drain strips a minimum of 12" (300 mm) such that flow is not impeded. Connect drain strips to leveling pads by embedding strip ends at least 4" (100 mm) into the no. 57 stone.

Construct drains in accordance with Section 816 of the *Standard Specifications*. Provide drains with positive drainage toward outlets.

D. Shotcreting

Perform shotcreting in accordance with the contract and accepted submittals. Use nozzlemen who were accepted in the Soil Nail Wall Contractor personnel and experience submittal and made satisfactory preconstruction test panels.

Clean the excavation face and ungrouted zones of drill holes near the face of loose materials, mud, rebound and other foreign material. Moisten surfaces to receive shotcrete. Secure reinforcement to prevent movement and vibration while shotcreting.

Direct shotcrete at right angles to the excavation face except when placing shotcrete around reinforcing bars. Rotate nozzle steadily in a small circular pattern. Apply shotcrete from the bottom up. Make shotcrete surface uniform and free of sloughing or sagging.

Completely fill ungrouted zones of drill holes near the excavation face and any other voids with shotcrete. Consider subsurface conditions and resulting potential for voids when estimating shotcrete quantities. No additional payment will be made for unanticipated shotcrete quantities.

Taper construction joints to a thin edge over a minimum distance equal to the shotcrete thickness. Wet the joint surface before applying shotcrete on adjacent sections.

Repair surface defects as soon as possible after placement. Remove any shotcrete which lacks uniformity, exhibits segregation, honeycombing or lamination or contains any voids or sand pockets and replace with fresh shotcrete to the satisfaction of the Engineer.

E. Leveling Pads, Concrete Facing and Concrete Barrier Rails with Moment Slabs

Construct leveling pads and drains at elevations and with dimensions shown in the accepted submittals. Construct drains in accordance with Section 816 of the *Standard Specifications*. Compact no. 57 stone for aggregate leveling pads with a vibratory compactor to the satisfaction of the Engineer.

Construct cast-in-place reinforced concrete facing in accordance with the accepted submittals and Section 420 of the *Standard Specifications*. Do not remove forms until concrete achieves a minimum compressive strength of 2400 psi (16.5 MPa). Unless required otherwise on the plans, provide a Class 2 Surface Finish for concrete facing in accordance with Article 420-17 of the *Standard Specifications*.

Construct concrete facing joints at a maximum spacing of 30 ft (9 m) unless required otherwise on the plans. Half-inch (13 mm) thick expansion joints in accordance with Article 420-10 of the *Standard Specifications* are required every third joint. Half-inch (13 mm) deep grooved contraction joints in accordance with Subarticle 825-10(B) of

the *Standard Specifications* are required for the remaining joints. Stop reinforcement 2" (50 mm) from either side of expansion joints.

If a brick veneer is required as shown on the plans, construct brick masonry in accordance with Section 830 of the *Standard Specifications*. Anchor brick veneers to concrete facing with approved brick to concrete type anchors according to the manufacturer's specifications with a minimum vertical spacing of 16" (400 mm) and a minimum horizontal spacing of 32" (800 mm) with each row staggered 16" (400 mm) from the row of anchors above and below.

Construct concrete barrier rails with moment slabs in accordance with the plans. Construct moment slabs in accordance with Section 420 of the *Standard Specifications* and concrete barrier rails in accordance with Subarticle 460-3(C) of the *Standard Specifications*. Seal joints above and behind soil nail walls between concrete facing and ditches with joint sealer as shown on the plans.

6.0 CONSTRUCTION RECORDS

Provide 2 original hard copies of soil nail wall construction records including the following within 24 hours of completing each lift.

1. Names of Soil Nail Wall Contractor, Superintendent, Nozzleman, Drill Rig Operator, Project Manager and Design Engineer
2. Wall description, county, NCDOT contract, TIP and WBS element number
3. Wall station and number and lift location, dimensions, elevations and description
4. Soil nail locations, diameters, lengths and inclinations, bar types, sizes and grades, corrosion protection and temporary casing information
5. Date and time drilling begins and ends, soil nail bars are placed, grout and shotcrete are mixed and/or arrives on-site and grout placement and shotcrete application begins and ends
6. Grout volume, temperature, flow and density records
7. Ground and surface water conditions and elevations, if applicable
8. Weather conditions including air temperature at time of grout placement and shotcrete application
9. All other pertinent details related to soil nail wall construction

After completing each soil nail wall or stage of a soil nail wall, submit electronic copies (PDF on CD or DVD) of all corresponding construction records.

7.0 SOIL NAIL TESTING

Verification and proof tests are required as shown on the plans. For this provision, “verification tests” are performed on test nails not incorporated into the wall, i.e., sacrificial soil nails and “proof tests” are performed on test nails incorporated into the wall, i.e., production soil nails assuming test nails are acceptable in accordance with this provision. “Verification test nails” refer to soil nails on which verification tests are performed and “proof test nails” refer to soil nails on which proof tests are performed.

In general, 1 verification test for each soil type with a minimum of 2 tests per soil nail wall and proof tests on 5 percent of production soil nails with a minimum of 1 test per nail row are required. More or less soil nail testing may be required depending on the subsurface conditions encountered. The Engineer will decide the actual number and locations of verification and proof tests. The approximate locations of known verification test nails are shown on the plans.

Do not test soil nails until grout and shotcrete achieve the required 3 day compressive strength. Do not begin construction of any production soil nails until verification tests are satisfactorily completed.

A. Testing Equipment

Use testing equipment that includes the following.

- 2 dial gauges with rigid supports
- hydraulic jack and pressure gauge
- jacking block or reaction frame
- electrical resistance load cell (verification tests only)

Use dial gauges capable of measuring to 0.001” (0.025 mm) and accommodating the maximum anticipated movement. Provide pressure gauges graduated in 100 psi (690 kPa) increments or less. Submit identification number and calibration records for each load cell, jack and pressure gauge with the soil nail wall construction plan. Calibrate the jack and pressure gauge as a unit.

Align testing equipment to ensure uniform loading. Use a jacking block or reaction frame that does not damage the shotcrete or contact the shotcrete face within 3 ft (1 m) of test nails. Align dial gauges within 5 degrees of the test nail axis. Place dial gauges opposite each other on either side of the test nail. Set up testing equipment and measuring devices such that resetting or repositioning the components before completing testing is not required.

B. Test Nails

Test nails have both unbonded and bond lengths. Grout only the bond lengths before testing. Minimum required unbonded and bond lengths are 3 ft (1 m) and 10 ft (3 m), respectively.

Soil nail bars for production soil nails may be overstressed under higher test nail loads. Use larger or higher grade steel bars to allow for higher loads instead of shortening bond lengths to less than the minimum. Any costs associated with higher capacity bars will be considered incidental to the soil nail testing pay items.

C. Verification Tests

Install sacrificial soil nails in accordance with the accepted submittals and this provision. Use the same equipment, methods and drill hole diameter for sacrificial soil nails as will be used for production soil nails.

Use the following equation to determine maximum bond lengths, L_{BVT} (ft or m), for verification test nails.

$$L_{BVT} \leq \frac{C_{RT} \times A_t \times f_y}{Q_{ALL} \times 3},$$

where,

C_{RT} = reduction coefficient, 0.9 for Grade 60 and 75 (420 and 520) bars or 0.8 for Grade 150 (1035) bars,

A_t = bar area (in² or m²),

f_y = bar yield stress (ksi or kPa) and

Q_{ALL} = allowable unit grout/ground bond strength (kips/ft or kN/m).

Use the following equation to determine design test loads, DTL_{VT} (kips or kN), for verification test nails.

$$DTL_{VT} = L_{BVT} \times Q_{ALL}$$

Calculate DTL_{VT} based on as-built bond lengths. Perform verification tests by incrementally loading test nails to failure or a maximum test load of 300 percent of DTL_{VT} according to the following schedule.

Load	Hold Time
AL*	1 minute
0.25 DTL_{VT}	10 minutes
0.50 DTL_{VT}	10 minutes
0.75 DTL_{VT}	10 minutes
1.00 DTL_{VT}	10 minutes
1.25 DTL_{VT}	10 minutes
1.50 DTL_{VT}	60 minutes (creep test)
1.75 DTL_{VT}	10 minutes
2.00 DTL_{VT}	10 minutes
2.50 DTL_{VT}	10 minutes

3.00 DTL _{VT}	10 minutes
AL*	1 minute

*Alignment load (AL) is the minimum load required to align testing equipment and should not exceed 0.05 DTL_{VT}.

Reset dial gauges to zero after applying alignment load. Record test nail movement at each load increment and permanent set after load is reduced to alignment load.

Monitor test nails for creep at the 1.50 DTL_{VT} load increment. Measure and record test nail movement during the creep portion of the test at 1, 2, 3, 5, 6, 10, 20, 30, 50 and 60 minutes. Repump jack as needed to maintain the intended load during hold times.

D. Proof Tests

Use the following equation to determine maximum bond lengths, L_{BPT} (ft or m), for proof test nails.

$$L_{BPT} \leq \frac{C_{RT} \times A_t \times f_y}{Q_{ALL} \times 1.5},$$

where variables are as defined in Item C above.

Use the following equation to determine design test loads, DTL_{PT} (kips or kN), for proof test nails.

$$DTL_{PT} = L_{BPT} \times Q_{ALL}$$

Calculate DTL_{PT} based on as-built bond lengths. Perform proof tests by incrementally loading test nails to failure or a maximum test load of 150 percent of DTL_{PT} according to the following schedule.

Load	Hold Time
AL*	Until movement stabilizes
0.25 DTL _{PT}	Until movement stabilizes
0.50 DTL _{PT}	Until movement stabilizes
0.75 DTL _{PT}	Until movement stabilizes
1.00 DTL _{PT}	Until movement stabilizes
1.25 DTL _{PT}	Until movement stabilizes
1.50 DTL _{PT}	10 or 60 minutes (creep test)
AL*	1 minute

*Alignment load (AL) is the minimum load required to align testing equipment and should not exceed 0.05 DTL_{PT}.

Reset dial gauges to zero after applying alignment load. Record test nail movement at each load increment and monitor test nails for creep at the 1.50 DTL_{PT} load increment.

Measure and record test nail movement at 1, 2, 3, 5, 6 and 10 minutes. When the test nail movement between 1 minute and 10 minutes exceeds 0.04" (1 mm), maintain the maximum test load for an additional 50 minutes and record movements at 20, 30, 50 and 60 minutes. Repump jack as needed to maintain the intended load during hold times.

E. Test Nail Acceptance

Test nail acceptance is based on the following criteria.

1. For verification tests, total creep movement is less than 0.08" (2 mm) between the 6 and 60 minute readings and creep rate is linear or decreasing throughout the creep test load hold time.
2. For proof tests, total creep movement is less than 0.04" (1 mm) between the 1 and 10 minute readings or less than 0.08" (2 mm) between the 6 and 60 minute readings and creep rate is linear or decreasing throughout the creep test load hold time.
3. Total test nail movement at maximum test load exceeds 80 percent of the theoretical elastic elongation of the test nail unbonded length.
4. Pullout failure does not occur at or before the 2.0 DTL_{VT} or 1.5 DTL_{PT} load increment. Pullout failure is defined as the inability to increase the load while test nail movement continues. Record the pullout failure load as part of the test data.

Maintain stability of test nail unbonded lengths for subsequent grouting. If the test nail unbonded length of a proof test nail can not be satisfactorily grouted after testing, do not incorporate the test nail into the wall and replace the nail with another production soil nail at no additional cost to the Department.

F. Test Nail Results

Submit 2 original hard copies of test nail records including movement versus load plots for each load increment within 24 hours of completing each test. The Engineer will review the test records and associated construction records to determine if the test nail is acceptable.

If the Engineer determines a verification test nail is unacceptable, revise the soil nail wall design and/or installation methods. Submit a revised soil nail wall design and/or construction plan for review and acceptance and provide an acceptable verification test nail with the revised design and/or installation methods at no additional cost to the Department.

If the Engineer determines a proof test nail is unacceptable, either perform additional proof tests on adjacent production soil nails or revise the soil nail wall design for the production soil nails represented by the unacceptable proof test nail as determined by the Engineer. Submit a revised soil nail wall design and/or construction plan for review and acceptance and provide an acceptable proof test nail with the revised design and/or

installation methods at no additional cost to the Department. If required, remove representative production soil nails and/or provide new production soil nails with the revised design and/or installation methods at no additional cost to the Department.

After completing soil nail testing for each wall or wall stage, submit electronic copies (PDF on CD or DVD) of all corresponding test records.

8.0 MEASUREMENT AND PAYMENT

Soil Nail Retaining Walls will be measured and paid for in square feet (meters). Soil nail walls will be measured as the exposed face area with the wall height equal to the difference between the top and bottom of wall elevation. The top of wall elevation is defined as the top of concrete facing. The bottom of wall elevation is defined as where the finished grade intersects the front face of the soil nail wall. No payment will be made for portions of soil nail walls below bottom of wall elevations.

The contract unit price bid for *Soil Nail Retaining Walls* will be full compensation for design, submittals, furnishing labor, tools, equipment and soil nail wall materials, excavating, installing soil nails and wall drainage systems, grouting, shotcreting including test panels, welding and providing reinforcement, leveling pads, concrete facing and any incidentals necessary to design and construct soil nail walls in accordance with this provision. If necessary, the contract unit price bid for *Soil Nail Retaining Walls* will also be full compensation for providing brick veneers in accordance with the contract.

The contract unit price bid for *Soil Nail Retaining Walls* does not include the cost for fences, hand rails, ditches, guardrail and barriers. With the exception of concrete barrier rails with moment slabs, see roadway pay items for these items.

Concrete Barrier Rail will be measured and paid for in accordance with Article 460-4 of the *Standard Specifications*. The contract unit price bid for *Concrete Barrier Rail* will be full compensation for providing concrete barrier rails with moment slabs in accordance with the contract and no separate payment for moments slabs will be made.

Soil Nail Verification Tests and *Soil Nail Proof Tests* will be measured and paid for in units of each, depending on the type of test. Soil nail tests will be measured as the number of initial verification or proof tests required by the Engineer or as shown on the plans. No payment will be made for subsequent tests performed on the same test nails or replacement nails. The contract unit price bid for *Soil Nail Verification Tests* and *Soil Nail Proof Tests* will be full compensation for soil nail testing in accordance with Section 7.0 of this provision.

Payment will be made under:

Pay Item	Pay Unit
Soil Nail Retaining Walls	Square Foot (Meter)
Soil Nail Verification Tests	Each

Soil Nail Proof Tests

Each