TECHNICAL SPECIFICATION
FOR
PERMANENT SOIL NAILS AND WALL EXCAVATION

1. Description

   a) The work shall consist of constructing permanent soil nail retaining walls as specified herein and shown on the plans.

   b) Soil nailing work shall include excavating in accordance with the staged lifts shown in the plans; drilling soil nail drillholes to the specified minimum length and orientation indicated on the plans; providing, placing and grouting the encapsulated or epoxy coated nail bar tendons into the drillholes; placing drainage elements; placing shotcrete reinforcement; applying shotcrete facing over the reinforcement; attaching bearing plates and nuts; performing nail testing; and installing instrumentation (if required).

   c) The work covered by this item shall consist of furnishing all labor, materials and equipment.

2. Materials

   a) Solid Bar Nail Tendons: AASHTO M31/ASTM A615, Grade 60. Deformed bar, continuous without splices or welds, new, straight, undamaged, bare or epoxy coated or encapsulated as shown on the Plans. 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 (e.g. continuous threadbars) or may be cut into a reinforcing bar. If threads are cut into a reinforcing bar, provide the next larger bar number designation from that shown on the Plans, at no additional cost.

   b) Fusion Bonded Epoxy Coating: ASTM A775. Minimum 0.3 mm thickness 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.

   c) Encapsulation: Minimum 1 mm thick corrugated HDPE tube conforming to AASHTO M252 or corrugated PVC tube conforming to ASTM D1784, Class 13464-B. Encapsulation shall provide at least 5 mm of grout cover over the nail bar and be resistant to ultra violet light degradation, normal handling stresses, and grouting pressures. Factory fabrication of the encapsulation is preferred. Upon the Engineers approval, the encapsulation may be field fabricated if done in strict accordance with the manufacturer's recommendations.

   d) Centralizers: Manufactured from Schedule 40 PVC pipe or tube, steel or other material not detrimental to the nail steel (wood shall not be used); securely attached to the nail bar; sized to position the nail bar within 1 inch of the center of the drillhole; sized to allow tremie pipe insertion to the bottom of the drillhole; and sized to allow grout to freely flow up the drillhole.

e) Nail Grout: Neat cement or sand/cement mixture with a minimum 3-day compressive strength of 1500 psi and a minimum 28-day compressive strength of 3000 psi per AASHTO T106/ASTM C109.

f) Admixtures: AASHTO M194/ASTM C494. Admixtures that control bleed, improve flowability, reduce water content and retard set may be used in the grout subject to review and acceptance by the Engineer. Accelerators are not permitted. Expansive admixtures may only be used in grout used for filling sealed encapsulations. Admixtures shall be compatible with the grout and mixed in accordance with the manufacturer's recommendations.

g) Cement: AASHTO M85/ASTM C150, Type I, II, III or V.

h) Fine Aggregate: AASHTO M6/ASTM C33.

i) Film Protection: Polyethylene film per AASHTO M171.

j) Bar Couplers: Bar couplers shall develop the full ultimate tensile strength of the bar as certified by the manufacturer.

3. Construction Requirements

a) Site Drainage Control

Provide positive control and discharge of all surface water that will affect construction of the soil nail retaining wall. Maintain all pipes or conduits used to control surface water during construction. Repair damage caused by surface water at no additional cost. Upon substantial completion of the wall, remove surface water control pipes or conduits from the site. Alternatively, with the approval of the Engineer, pipes or conduits that are left in place, may be fully grouted and abandoned or left in a way that protects the structure and all adjacent facilities from migration of fines through the pipe or conduit and potential ground loss.

The regional groundwater table is anticipated to be below the level of the wall excavation based on the results of the geotechnical site investigation. Localized areas of perched water or seepage may be encountered during excavation at the interface of geologic units or from localized groundwater seepage areas.

Immediately contact the Engineer if unanticipated existing subsurface drainage structures are discovered during excavation. Suspend work in these areas until remedial measures meeting the Engineer's approval are implemented. Capture surface water runoff flows and flows from existing subsurface drainage structures independently of the wall drainage network and convey them to an outfall structure or storm sewer, as approved by the Engineer. Cost of remedial measures required to capture and dispose of water resulting from encountering unanticipated subsurface drainage structures will be paid for as Extra Work.

b) Excavation

Coordinate the work and the excavation so the soil nail wall is safely constructed. Perform the wall construction and excavation sequence in accordance with the Plans and approved submittals. No excavations steeper than those specified herein or shown on the Plans will be made above or below the soil nail wall without written approval of the Engineer.

1. Excavation and Wall Alignment Survey Control

Unless specified otherwise, the Engineer will provide survey reference and control points at or offset along the top of wall alignment at approximate 30 foot intervals prior to starting wall excavation. The Contractor will be responsible for providing the necessary survey and alignment control during excavation of each lift, locating and drilling each drillhole within the allowable tolerances and for performing the wall excavation and nail installation in a manner which will allow for constructing the shotcrete construction facing to the specified minimum thickness and such that the finish shotcrete permanent structural facing can be constructed to the specified minimum thickness and to the line and grade indicated in the Plans. Where the as-built location of the front face of the shotcrete exceeds the allowable tolerance from the wall control line shown on the Plans, the Contractor will be responsible for determining and bearing the cost of remedial measures necessary to provide proper attachment of nail head bearing plate connections and satisfactory placement of the final facing, as called for on the Plans.

2. General Excavation

Complete clearing, grubbing, grading and excavation above and behind the wall before commencing wall excavation. Do not over excavate the original ground behind the wall or at the ends of the wall, beyond the limits shown on the Plans. Excavation shall proceed from the top down in a horizontal staged excavation lift sequence with the ground level for each lift excavated no more than mid-height between adjacent nail rows, as illustrated on the Plans. Do not excavate the full wall height to the final wall alignment as shown on the Plans but maintain a working bench of native material to serve as a platform for the drilling equipment. The bench shall be wide enough to provide a safe working area for the drill equipment and workers.

Perform rock blasting within 200 feet of the soil nail wall using controlled blasting techniques designed by a qualified blasting consultant or a Professional Engineer registered in the State of Tennessee. Blasting shall not damage completed soil nail work or disrupt the remaining ground to be soil nailed or shotcreted. Repair damaged areas at no additional cost.

3. Soil Nail Wall Structure Excavation

Structure excavation in the vicinity of the wall face will require special care and effort compared to general earthwork excavation. The excavation Contractor should take this into account during bidding. Due to the close coordination required between the soil nail Contractor and the excavation Contractor, the excavation Contractor shall perform the structure excavation for the soil nail wall under the direction of the soil nail specialty Contractor. The structure excavation pay limits are shown on the Plans.

Excavate to the final wall face using procedures that: (1) prevent over excavation; (2) prevent ground loss, swelling, air slaking, or loosening; (3)

prevent loss of support for completed portions of the wall; (4) prevent loss of soil moisture at the face; and (5) and prevent ground freezing. Costs associated with additional thickness of shotcrete or concrete or other remedial measures required due to irregularities in the cut face, excavation overbreak or inadvertent over excavation, shall be borne by the Contractor.

The exposed unsupported final excavation face cut height shall not exceed the vertical nail spacing plus the required reinforcing lap or the short-term stand-up height of the ground, whichever is less. Complete excavation to the final wall excavation line and application of the shotcrete 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 show that the delay will not adversely affect the excavation face stability. A polyethylene film over the face of the excavation may reduce degradation of the cut face caused by changes in moisture. Damage to existing structures or structures included in the Work shall be repaired and paid by the Contractor where approval is granted for the extended face exposure period.

At the Contractor's option, during each excavation lift, nails may be drilled and installed through a temporary stabilizing berm, as illustrated on the Plans. Purpose of the stabilizing berm is to prevent or minimize instability or sloughing of the final excavation face due to ground conditions and/or drilling action. The stabilizing berm geometry illustrated on the plans shows the top of berm extending horizontally out from the bottom front face of the overlying shotcrete a distance of 1 foot and cut down from that point to the base grade for that excavation lift at a slope not steeper than 1H:1V. The Contractor may use a different berm geometry than illustrated on the Plans, upon satisfactory demonstration that the different geometry provides satisfactory performance. Following the installation of nails in that lift, excavate the temporary stabilizing berm to the final wall face excavation line and clean the final excavation face of all loose materials, mud, rebound and other foreign matter which could prevent or reduce shotcrete bond. Ensure that installed nails and corrosion protection are not damaged during excavation of the stabilizing berm. Repair or replace nails or corrosion protection damaged or disturbed during excavation of the stabilizing berm, to the Engineer's satisfaction, at no additional cost. Do not excavate the stabilizing berm until the nail grout has aged for at least 24 hours. Remove hardened nail grout protruding from the final wall excavation line more than 2 inches in a manner that prevents fracturing the grout at the nail head. Sledgehammer removal of the grout is not allowed. The use of hand held rock chippers is acceptable provided their use does not damage or disturb the remaining grout at the nail head, the nail bar or corrosion protection. Alternative excavation and soil nail installation methods that meet these objectives may be submitted to the Engineer for review in accordance with the Submittal section.

Excavation to the next lift shall not proceed until nail installation, reinforced shotcrete placement, attachment of bearing plates and nuts and nail testing has been completed and accepted in the current lift. Nail grout

and shotcrete shall have cured for at least 72 hours or attained at least their specified 3-day compressive strength before excavating the next underlying lift. Excavating the next lift in less than 72 hours will only be allowed if the Contractor submits compressive strength test results, for tests performed by a qualified independent testing lab, verifying that the nail grout and shotcrete mixes being used will provide the specified 3-day compressive strengths in the lesser time.

Notify the Engineer immediately if raveling or local instability of the final wall face excavation occurs. Unstable areas shall be temporarily stabilized by means of buttressing the exposed face with an earth berm or other methods. Suspend work in unstable areas until remedial measures are developed.

4. Wall Discontinuities

Where the Contractor's excavation and installation methods result in a discontinuous wall along any nail row, the ends of the constructed wall section 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, prevent sloughing or failure of the temporary slopes at the end of each wall section.

5. Excavation Face Protrusions, Voids or Obstructions

Remove all or portions of cobbles, boulders, rubble or other subsurface obstructions encountered at the wall final excavation face which will protrude into the design shotcrete facing. Determine method of removal of face protrusions, including method to safely secure remnant pieces left behind the excavation face and for promptly backfilling voids resulting from removal of protrusions extending behind the excavation face. Notify the Engineer of the proposed method(s) for removal of face protrusions at least 24 hours prior to beginning removal. Voids overbreak or over-excavation beyond the plan wall excavation line resulting from the removal of face protrusions or excavation operations shall be backfilled with shotcrete or concrete, as approved by the Engineer. Removal of face protrusions and backfilling of voids or over-excavation is considered incidental to the work. Cost due to removal of unanticipated man-made obstructions will be paid as Extra Work.

c) Nail Installation

Determine the required drillhole diameter(s), drilling method, grout composition and installation method necessary to achieve the nail pullout resistance(s) specified herein or on the Plans, in accordance with the nail testing acceptance criteria in the Nail Testing section.

No drilling or installation of production nails will be permitted in any soil/rock unit until successful pre-production verification testing of nails is completed in that unit and approved by the Engineer. Install verification test nails using the same equipment, methods, nail inclination and drillhole diameter as planned for the production nails. Perform pre-production verification tests in accordance with

the Verification Testing Section prior to starting wall excavation and prior to installation of production nails in the specific lift in which the designated verification test nails are located. The number and location of the verification tests will be as indicated on the Plans or specified herein. Verification test nails may be installed through either the existing slope face prior to start of wall excavation, drill platform work bench, stabilization berm or into slot cuts made for the particular lift in which the verification test nails are located. Slot cuts will only be large enough to safely accommodate the drill and test nail reaction setup. Subject to the Engineer's approval, verification test nails may also be installed at angle orientations other than perpendicular to the wall face or at different locations than specified, as long as the Contractor can demonstrate that the test nails will be bonded into ground which is representative of the ground at the verification test nail locations designated on the Plans or herein. Install the production soil nails before the application of the reinforced shotcrete facing. At the Contractor's request and subject to the Engineer's written approval, the shotcrete facing may be placed before drilling and installing the nails. Provide a blockout through the shotcrete facing at drillhole locations using PVC pipe or other suitable material, to prevent damage to the facing during drilling. As part of the required construction submittals, provide the Engineer with acceptable structural design calculations demonstrating that the facing structural capacity will not be reduced and that the bearing plates are adequate to span the nail drillhole blockout through the construction facing. If this requires larger size bearing plates and/or additional reinforcement beyond that detailed on the Plans, the extra cost will be incidental.

Where necessary for stability of the excavation face, the Contractor shall have the option of placing a sealing layer (flashcoat) of unreinforced shotcrete or steel fiber reinforced shotcrete or of drilling and grouting of nails through a temporary stabilizing berm of native soil to protect and stabilize the face of the excavation per Section 3.b.3 Wall Structure Excavation. Cost shall be incidental to the Work.

The Engineer may add, eliminate, or relocate nails to accommodate actual field conditions. Cost adjustments associated with these modifications shall be made in accordance with the General Provisions of the Contract. The cost of additional material, or installation modifications resulting from actions of the Contractor shall be borne by the Contractor.

1. Drilling

   The drill holes for the soil nails shall be made at the locations, orientations, and lengths shown on the Plans or as directed by the Engineer. Select drilling equipment and methods suitable for the ground conditions encountered. Select drillhole diameter(s) required to develop the specified pullout resistance and to also provide a minimum 1-inch grout cover over bare or epoxy coated bars or minimum 1/2-inch grout cover over the encapsulation of encapsulated nails. A minimum required drillhole diameter is shown on the plans. It is the Contractor's responsibility to determine the final drillhole diameter(s) required to provide the specified pullout resistance. Use of drilling muds such as bentonite slurry to assist in drill cutting removal is not allowed but air may be used. With the Engineer's approval, the Contractor may be allowed to use water or foam flushing upon successful demonstration, at the

Contractor's cost, that the installation method still provides adequate nail pullout resistance. If caving ground is encountered, use cased drilling methods to support the sides of the drillholes. Where hard drilling conditions such as rock, cobbles, boulders, or obstructions are encountered, percussion or other suitable drilling equipment capable of drilling and maintaining stable drillholes through such materials will be used.

Immediately suspend or modify drilling operations if ground subsidence is observed, if the soil nail wall is adversely affected, or if adjacent structures are damaged from the drilling operation. Immediately stabilize the adverse conditions at no additional cost.

2. Nail Bar Installation

Provide nail bars in accordance with the schedules included in the Plans. Provide centralizers sized to position the bar within 1 inch of the center of the drillhole. Position centralizers as shown on the Plans so their maximum center-to-center spacing does not exceed 10 feet. Also locate centralizers within 2feet from the top and bottom of the drillhole. Securely attach centralizers to the bar so they will not shift during handling or insertion into the drill hole yet will still allow grout tremie pipe insertion to the bottom of drillhole and allow grout to flow freely up the hole.

Inspect each nail bar before installation and repair or replace damaged bars or corrosion protection. Check uncased drillholes for cleanliness prior to insertion of the soil nail bar. Insert nail bars with centralizers into the drill hole to the required length without difficulty and in a way that prevents damage to the drill hole, bar, or corrosion protection. Do not drive or force partially inserted soil nails into the hole. Remove nails which cannot be fully inserted to the design depth and clean the drill hole to allow unobstructed installation.

When using cased or hollow stem auger drilling equipment which does not allow for the centralizers to pass through the casing or auger stem, the Contractor may delete the centralizers if the neat cement grout pumped through the casing is placed using grout pressures greater than 150 psi or if the sand-cement grout placed through the stem of the auger has a slump of 8 inches or less.

3. Nail Installation Tolerances

Nails shall not extend beyond the right-of-way or easement limits shown on the Plans. Nail location and orientation tolerances are:

- Nail head location, deviation from plan design location; 6 inches any direction.
- Nail inclination, deviation from plan; + or - 3 degrees.
- Location tolerances are applicable to only one nail and not accumulative over large wall areas. Center nail bars within 1 inch of the center of the drillhole

Soil nails that do not satisfy the specified tolerances, due to the Contractor's installation methods, will be replaced at no additional cost. Backfill abandoned nail drill holes with tremied grout. Nails that encounter unanticipated obstructions during drilling shall be relocated, as approved by the Engineer. Cost of drilling and backfilling drillholes abandoned due to unanticipated obstructions will be paid as Extra Work.

d) Grouting

1. Grout Mix Design

Use a neat cement grout or sand-cement grout. Submit the proposed nail grout mix design to the Engineer for review and approval. The design mix submittal shall include compressive strength test results verifying that the proposed mix will have a minimum 3-day compressive strength of 1500 psi and minimum 28-day compressive strength of 3000 psi.

2. Grout Testing

Previous test results for the proposed grout mix completed within one year of the start of work may be submitted for initial verification of the required compressive strengths for installation of pre-production verification test nails and initial production nails. During production, nail grout shall be tested by the Contractor in accordance with AASHTO T106/ASTM C109 at a frequency of no less than one test for every 50 cubic yards of grout placed. Provide grout cube test results to the Engineer within 24 hours of testing.

3. Grouting Equipment

Grout equipment shall produce a uniformly mixed grout free of lumps and undispersed cement, and be capable of continuously agitating the mix. Use a positive displacement grout pump equipped with a pressure gauge that can measure at least twice but no more than three times the intended grout pressure. Size the grouting equipment to enable the entire nail to be grouted in one continuous operation. Place the grout within 60 minutes after mixing or within the time recommended by the admixture manufacturer, if admixtures are used. Grout not placed in the allowed time limit will be rejected.

4. Grouting Methods

Grout the drillhole after installation of the nail bar. Each drillhole will be grouted within 2 hours of completion of drilling, unless otherwise approved by the Engineer. Inject the grout at the lowest point of each drill hole through a grout tube, casing, hollow-stem auger, or drill rods. Keep the outlet end of the conduit delivering the grout below the surface of the grout as the conduit is withdrawn to prevent the creation of voids. Completely fill the drillhole 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 nails. At the Contractor’s option, the grout tube may remain in the hole provided it is filled with grout. Grouting before

insertion of the nail is allowed provided the nail bar is immediately inserted through the grout to the specified length without difficulty.

During casing removal for drillholes advanced by either cased or hollow-stem auger methods, maintain sufficient grout level within the casing to offset the external groundwater/soil pressure and prevent hole caving. Maintain grout head or grout pressures sufficient to ensure that the drillhole will be completely filled with grout and to prevent unstable soil or groundwater from contaminating or diluting the grout. Record the grout pressures for soil nails installed using pressure-grouting techniques. Control grout pressures to prevent excessive ground heave or fracturing.

Remove the grout and nail if grouting is suspended for more than 30 minutes or does not satisfy the requirements of this specification or the Plans, and replace with fresh grout and undamaged nail bar at no additional cost.

e) Nail Testing

Perform both verification and proof testing of designated test nails. Perform pre-production verification tests on sacrificial test nails at locations shown on the Plans or listed herein. Perform proof tests on production nails at locations selected by the Engineer. Required nail test data shall be recorded. Do not perform nail testing until the nail grout and shotcrete facing have cured for at least 72 hours and attained at least their specified 3-day compressive strength. Testing in less than 72 hours will only be allowed if the Contractor submits compressive strength test results, for tests performed by a qualified independent testing lab, verifying that the nail grout and shotcrete mixes being used will provide the specified 3-day compressive strengths in the lesser time.

1. Proof Test Nail Unbonded Length

Provide temporary unbonded lengths for each test nail. Isolate the test nail bar from the shotcrete facing and/or the reaction frame used during testing. Isolation of a test nail through the shotcrete facing shall not affect the location of the reinforcing steel under the bearing plate. Accepted proof test nails may be incorporated as production nails provided the temporary test unbonded length is fully grouted subsequent to testing. Submit the proposed test nail isolation methods, methods for providing an unbonded test length and methods for grouting the unbonded length subsequent to testing to the Engineer for review and approval in accordance with the Submittals section. Where temporary casing of the unbonded length of test nails is provided, install the casing in a way that prevents any reaction between the casing and the grouted bond length of the nail and/or the stressing apparatus.

2. Testing Equipment

Testing equipment shall include dial gauges, dial gauge support, jack and pressure gauge, electronic load cell, and a reaction frame. The load cell is required only for the creep test portion of the verification test. Provide description of test setup and jack, pressure gage and load cell calibration curves in accordance with Submittals section.

Design the testing reaction frame to be sufficiently rigid and of adequate dimensions such that excessive deformation of the testing equipment does not occur. If the reaction frame will bear directly on the shotcrete facing, design it to prevent cracking of the shotcrete. Independently support and center the jack over the nail bar so that the bar does not carry the weight of the testing equipment. Align the jack, bearing plates, and stressing anchorage with the bar such that unloading and repositioning of the equipment will not be required during the test.

Apply and measure the test load with a hydraulic jack and pressure gage. The pressure gauge shall be graduated in 50-psi increments or less. The jack and pressure gauge shall have a pressure range not exceeding twice the anticipated maximum test pressure. Jack ram travel shall be sufficient to allow the test to be done without resetting the equipment. Monitor the nail load during verification tests with both the pressure gauge and the load cell. Use the load cell to maintain constant load hold during the creep test load hold increment of the verification test.

Measure the nail head movement with a dial gauge capable of measuring to 0.001 inches. The dial gauge shall have a travel sufficient to allow the test to be done without having to reset the gauge. Visually align the gauge to be parallel with the axis of the nail and support the gauge independently from the jack, wall or reaction frame. Use two dial gauges when the test setup requires reaction against a soil cut face.

3. Pre-production Verification Testing of Sacrificial Test Nails

Pre-production verification testing shall be performed prior to installation of production nails to verify the Contractor's installation methods and nail pullout resistance. Perform pre-production verification tests at the locations and elevations shown on the Plans or herein and per Nail Installation Section 3(c), unless otherwise approved by the Engineer. Perform a minimum of 2 verification tests in each different soil/rock unit and for each different drilling/grouting method proposed to be used, at each wall location. Verification test nails will be sacrificial and not incorporated as production nails. Bare bars can be used for the sacrificial verification test nails.

Develop and submit the details of the verification testing arrangement including the method of distributing test load pressures to the excavation surface (reaction frame), test nail bar size, grouted drillhole diameter and reaction frame dimensioning to the Engineer for approval in accordance with Submittals section. Construct verification test nails using the same equipment, installation methods, nail inclination, and drillhole diameter as planned for the production nails. Changes in the drilling or installation method may require additional verification testing as determined by the Engineer and shall be provided at no additional cost. Payment for additional verification tests required due to differing site conditions, if determined by the Engineer, shall be per the Contract unit price.

Test nails shall have both bonded and temporary unbonded lengths. Prior to testing only the bonded length of the test nail shall be grouted. The

temporary unbonded length of the test nail shall be at least 3 feet. The bonded length of the test nail shall be determined based on the production nail bar grade and size such that the allowable bar structural load is not exceeded during testing, but shall not be less than 10 feet. The allowable bar structural load during testing shall not be greater than 90 percent of the yield strength for Grade 60 bars. The Contractor shall provide larger verification test bar sizes, if required to safely accommodate the 10-foot minimum test bond length and testing to 2 times the allowable pullout resistance requirements, at no additional cost.

The verification test bonded length L_{BV} shall not exceed the test allowable bar structural load divided by 2 times the allowable pullout resistance value. The following equation shall be used for determining the verification test nail maximum bonded length to be used to avoid structurally overstressing the verification test nail bar size:

$L_{BV} = C f_Y A_S / 2 Q_d$, or 10 feet, whichever is greater.

L_{BV} = Maximum Verification Test Nail Bonded Length (feet)
C = 0.9 for Grade 60 bars
f_Y = Bar Yield or Ultimate Stress (psi)
(Note: f_Y = 60 ksi for Grade 60 bars)
A_S = Bar Steel Area (in^2)
2 = Pullout resistance safety factor
Q_d = Allowable pullout resistance (lb/ft, pounds force per lineal foot of grouted nail length, specified herein or on the Plans)

The Design Test Load (DTL) during verification testing shall be determined by the following equation:
DTL = Design Test Load (lbs) = L_{BV} x Q_d
L_{BV} = As-built bonded test length (ft)
Q_d = Allowable pullout resistance (lbs/ft. pounds force per lineal foot of grouted nail length, specified herein or on the Plans)
MTL = 2.0 x DTL = Maximum Test Load (lb)

Verification test nails shall be incrementally loaded to a maximum test load of 200 percent of the Design Test Load (DTL) in accordance with the following loading schedule. The soil nail movements shall be recorded at each load increment.

VERIFICATION TEST LOADING SCHEDULE

LOAD	HOLD TIME
AL (.05 DTL max.)	1 minute
0.25 DTL	10 minutes
.50 DTL	10 minutes
0.75 DTL	10 minutes
1.00 DTL	10 minutes
1.25 DTL	10 minutes
1.50 DTL (Creep Test)	60 minutes
1.75 DTL	10 minutes
2.00 DTL(Max.Test Load)	10 minutes

The alignment load (AL) should be the minimum load required to align the testing apparatus and should not exceed 5 percent of the Design Test Load (DTL). Dial gauges should be set to "zero" after the alignment load has been applied.

Each load increment shall be held for at least 10 minutes. The verification test nail shall be monitored for creep at the 1.50 DTL load increment. Nail movements during the creep portion of the test shall be measured and recorded at 1 minute, 2, 3, 5, 6, 10, 20, 30, 50, and 60 minutes. The load during the creep test shall be maintained within 2 percent of the intended load by use of the load cell.

4. Proof Testing of Production Nails

Perform proof testing on 5 percent (1 in 20) of the production nails in each nail row or minimum of 1 per row as designated by the Engineer. A verification test nail successfully completed during production work shall be considered equivalent to a proof test nail and shall be accounted for in determining the number of proof tests required in that particular row.

Production proof test nails shall have both bonded and temporary unbonded lengths. Prior to testing only the bonded length of the test nail shall be grouted. The temporary unbonded length of the test nail shall be at least 3 feet. The bonded length of the test nail shall be determined based on the production nail bar grade and size such that the allowable bar structural load is not exceeded during testing, but shall not be less than 10 feet. Production proof test nails shorter than 4 meters in length may be constructed with less than the minimum 10-foot bond length with the unbonded length limited to 3 feet. The allowable bar structural load during testing shall not be greater than 90 percent of the yield strength for Grade 60 bars.

The proof test bonded length L_{BP} shall not exceed the test allowable bar load divided by 1.5 times the allowable pullout resistance value, or above minimum lengths, whichever is greater. The following equation shall be used for sizing the proof test nail bonded length to avoid overstressing the production nail bar size:

$L_{BP} = C f_Y A_S / 1.5 Q_d$, or above minimum lengths, whichever is greater.

L_{BP} = Maximum Proof Test Nail Bonded Length (ft)
C = 0.9 for Grade 60 bars
f_Y = Bar Yield or Ultimate Stress (psi)
(Note: f_Y = 60,000 psi for Grade 60 bars)
A_S = Bar Steel Area (in^2)
1.5 = Pullout resistance safety factor
Q_d = Allowable pullout resistance (lb/ft, pounds force per lineal foot of grouted nail length, specified herein or on the Plans)

The Design Test Load (DTL) during proof testing shall be determined by the following equation:

DTL = Design Test Load (lb) = L_{BP} x Q_d
L_{BP} = As-built bonded test length (ft)
Q_d = Allowable pullout resistance (lb/ft, pounds force per lineal foot of grouted nail length, specified herein or on the Plans)
MTL = 1.5 x DTL = Maximum Test Load (lb)

Proof tests shall be performed by incrementally loading the proof test nail to a maximum test load of 150 percent of the Design Test Load (DTL). The nail movement at each load shall be measured and recorded by the Engineer in the same manner as for verification tests. The test load shall be monitored by a jack pressure gauge with a sensitivity and range meeting the requirements of pressure gauges used for verification test nails. At load increments other than maximum test load, the load shall be held long enough to obtain a stable reading. Incremental loading for proof tests shall be in accordance with the following loading schedule. The soil nail movements shall be recorded at each load increment.

PROOF TEST LOADING SCHEDULE

LOAD	HOLD TIME
AL (.05 DTL max.)	Until Stable
0.25 DTL	Until Stable
0.50 DTL	Until Stable
0.75 DTL	Until Stable
1.00 DTL	Until Stable
1.25 DTL	Until Stable
1.50 DTL (Max. Test Load)	See Below

The alignment load (AL) should be the minimum load required to align the testing apparatus and should not exceed 5 percent of the Design Test Load (DTL). Dial gauges should be set to "zero" after the alignment load has been applied.

All load increments shall be maintained within 5 percent of the intended load. Depending on performance, either 10 minute or 60 minute creep tests shall be performed at the maximum test load (1.50 DTL). The creep

period shall start as soon as the maximum test load is applied and the nail movement shall be measured and recorded at 1 minutes, 2, 3, 5, 6, and 10 minutes. Where the nail movement between 1 minute and 10 minutes exceeds 1 mm, the maximum test load shall be maintained an additional 50 minutes and movements shall be recorded at 20 minutes, 30, 50, and 60 minutes.

5. Test Nail Acceptance Criteria

   a. For verification tests, a total creep movement of less than 2 mm per log cycle of time between the 6 and 60 minute readings is measured during creep testing and the creep rate is linear or decreasing throughout the creep test load hold period.

   b. For proof tests, a total creep movement of less than 1 mm is measured between the 1 and 10 minute readings or a total creep movement of less than 2 mm is measured between the 6 and 60 minute readings and the creep rate is linear or decreasing throughout the creep test load hold period.

   c. The total measured movement at the maximum test load exceeds 80 percent of the theoretical elastic elongation of the test nail unbonded length.

   d. A pullout failure does not occur at the maximum test load. Pullout failure is defined as the load at which attempts to further increase the test load simply result in continued pullout movement of the test nail. The pullout failure load shall be recorded as part of the test data.

   Successful proof tested nails meeting the above test acceptance criteria may be incorporated as production nails, provided that (1) the unbonded length of the test nail drillhole has not collapsed during testing, (2) the minimum required drillhole diameter has been maintained, (3) the specified corrosion protection is provided, and (4) the test nail length is equal to or greater than the scheduled production nail length. Test nails meeting these requirements shall be completed by satisfactorily grouting up the unbonded test length. Maintaining the temporary unbonded test length for subsequent grouting is the Contractor's responsibility. If the unbonded test length of production proof test nails cannot be satisfactorily grouted subsequent to testing, the proof test nail shall become sacrificial and shall be replaced with an additional production nail installed at no additional cost.

f) Test Nail Rejection

If a test nail does not satisfy the acceptance criterion, the Contractor shall determine the cause.

1. Verification Test Nails

The Engineer will evaluate the results of each verification test. Installation methods that do not satisfy the nail testing requirements shall be rejected. The Contractor shall propose alternative methods and install replacement verification test nails. Replacement test nails shall be installed and tested at no additional cost.

2. Proof Test Nails

The Engineer may require the Contractor to replace some or all of the installed production nails between a failed proof test nail and the adjacent passing proof test nail. Alternatively, the Engineer may require the installation and testing of additional proof test nails to verify that adjacent previously installed production nails have sufficient load carrying capacity. Contractor modifications may include, but are not limited to; the installation of additional proof test nails; increasing the drillhole diameter to provide increased capacity; modifying the installation or grouting methods; reducing the production nail spacing from that shown on the Plans and installing more production nails at a reduced capacity; or installing longer production nails if sufficient right-of way is available and the pullout capacity behind the failure surface controls the allowable nail design capacity. The nails may not be lengthened beyond the temporary construction easements or the permanent right-of-way shown on the Plans. Installation and testing of additional proof test nails or installation of additional or modified nails as a result of proof test nail failure(s) will be at no additional cost.

g) Nail Installation Records

Records documenting the soil nail wall construction will be maintained by the Engineer, unless specified otherwise. The Contractor shall provide the Engineer with as-built drawings showing as-built nail locations and as-built shotcrete facing line and grade within 5 days after completion of the shotcrete facing and as-built shotcrete permanent facing line and grade within 5 days after completion of the shotcrete permanent facing.

4. Method of Measurement

The unit of measurement for production soil nails will be per lineal foot. The length to be paid will be the length measured along the bar centerline from the back face of shotcrete to the bottom tip end of nail bar as shown on the Plans. No separate measurement will be made for proof test nails, which shall be considered incidental to production nail installation. Specified verification test nails will be measured on a unit basis for each verification test successfully completed. Failed verification test nails or additional verification test nails installed to verify alternative nail installation methods proposed by the Contractor will not be measured.

5. Basis of Payment

a) The accepted quantities of soil nails will be paid for at the Contract unit prices.

b) Payment will be full compensation for all labor, equipment, materials, material tests, field tests and incidentals necessary to acceptably fabricate and construct the soil nails and perform the wall alignment survey control, for the soil nail wall in accordance with all requirements of the Contract.

c) Payment will be made under the following bid items as set forth in the Bid Schedule:

Pay Item	Unit
Permanent Soil Nails	Lineal Feet
Verification Test Nails	Each