State of Ohio

Department of Transportation

SPECIAL PROVISION

SOIL NAIL RETAINING WALL

August 30, 2022

**Item Special - Retaining Wall, Soil Nail**

**Item Special - Retaining Wall, Soil Nail Verification Test**

**Item Special - Retaining Wall, Soil Nail Proof Test**

1. **Description**
2. **Qualification of Contractor**
3. **Definitions**
4. **Materials**
5. **Construction Requirements**
6. **Grouting**
7. **Testing**
8. **Method of Measurement**
9. **Basis of Payment**

**1.0 Description**

This work consists of constructing permanent soil nail retaining walls as specified herein and shown on the Plans. The Contractor shall furnish all labor, materials and equipment required for completing the work. The Contractor shall select the method of excavation, drilling method and equipment, drilled hole diameter(s), final soil nail length(s), and grouting procedures to meet the performance requirement specified herein. The required soil nail locations, orientations, and minimum lengths and the design loads are shown on the Plans. The term “Soil Nail” as used in these specifications is intended as a generic term and refers to a reinforcing bar grouted into a drilled hole installed in any type of ground. Soil nail walls are built from the top down in existing ground.

Soil nails are typically solid bars. Hollow Bar Soil Nails (HBSN) shall not be used unless specifically allowed in the Plans. When HBSN are used, the subsections herein referring to HBSN shall supersede the preceding section where they differ. Otherwise, the requirements for HBSN are the same as for solid bar soil nails.

Soil nailing work shall include excavating in accordance with the Plans; drilling soil nail drilled holes to the specified minimum length and orientation indicated on the Plans; furnishing, placing, and grouting the encapsulated or epoxy coated nail bar tendons into the drilled holes; placing drainage elements; placing shotcrete reinforcement; applying shotcrete facing over the reinforcement; attaching bearing plates and nuts; performing nail testing; and casting the final cast-in-place concrete facing.

Soil and rock properties, strength parameters, design requirements, and other criteria are shown on the Plans. Cast‐in‐place (CIP) concrete facing, shotcrete facing, and wall drainage construction are covered by the Standard Specifications.

**2.0 Qualification of Contractor**

Prior to the commencement of soil nailing work, the Contractor performing the soil nailing work shall submit to the Engineer a project reference list verifying the successful construction completion of at least 5 soil nail retaining wall projects during the past 3 years totaling at least 1200 square feet of wall face area and the installation of at least 500 soil nails. At least 3 of these soil nailing projects shall include installing soil nail walls under the foundation of existing structures. Include a brief description of each project with the Owner's name and current phone number.

The Contractor shall also submit to the Engineer a report which identifies the Contractor's personnel who will be performing and supervising the soil nailing work. The Contractor shall not use consultants or manufacturer's representatives to satisfy the requirements of this section. The report shall include the names of a Soil Nail Engineer, Soil Nail Site Supervisor, and Drill Operators. The report shall also contain a list of employer's names and telephone numbers, location and dates of previous permanent soil nailing or tieback projects, and the extent of work performed. This information must be verifiable. Further, in order to meet the requirements of ODOT Specification 108.05, the personnel performing soil nailing work shall have acquired work experience, which is not less than the level of experience as defined below.

The Engineer will accept or reject the Contractor's personnel within thirty (30) calendar days following the submission of the report of names and verifiable resume information. Soil nailing work shall not commence until the Engineer has provided a written letter of acceptance. In the event the Contractor elects to substitute personnel, submit verifiable resume information to the Engineer prior to that individual's performance of soil nailing work. The Engineer will accept or reject the Contractor's proposed substitute within fifteen (15) calendar days. The Engineer will take action afforded to him pursuant to ODOT Specifications, including but not limited to Specification 108.05, in order to be assured that all personnel have the sufficient and requisite skill and experience to perform properly the work assigned to them. The Engineer may suspend the work if the contractor uses unacceptable personnel. If work is suspended for use of unacceptable personnel, no adjustment in contract costs or contract time attributed to the suspension will be made.

**2.1 Soil Nail Engineer:** The Soil Nail Engineer shall be an Ohio Registered Professional Engineer and is responsible for overseeing the soil nailing work and verifying the results of the testing. The Soil Nail Engineer shall have three (3) years of construction experience in the installation of permanent soil nails or tiebacks and shall have overseen the successful installation of over 100 permanent soil nails or tiebacks. The work experience time period is computed by the addition of all documented durations of soil nailing or tieback work time on construction projects.

**2.2 Soil Nail Site Supervisor:** The Soil Nail Site Supervisor shall be present at the job site at all times during the performance of soil nailing work. The Soil Nail Site Supervisor shall have one (1) year of construction experience in the installation of permanent soil nails or tiebacks and shall have supervised the successful installation of over 100 permanent soil nails or tiebacks. The work experience time period is computed by the addition of all documented durations of soil nailing or tieback work time on construction projects.

**2.3 Drill Operators:** Drill operators shall have successfully installed at least 50 permanent soil nails or tiebacks.

**2.4 Construction Submittals:** Upon acceptance of the soil nailing Contractor’s qualifications submittal set forth in Section 2.0; submit 5 copies of the following information, in writing, to the Engineer for review and acceptance.

Provide submittal item numbers 1 through 1.f at least 15 calendar days prior to initiating the nail wall construction and submittal items 2 through 6 at least 15 calendar days prior to start of nail installation or incorporation of the respective materials into the Work:

1. The proposed start date and proposed detailed wall construction sequence including:

a. Plan describing how surface water will be diverted, controlled, and disposed of.

b. Proposed methods and equipment for excavating the soil and/or rock to each staged excavation lift, including the proposed grade elevations for each excavation lift shown on a wall elevation view.

c. Measures to ensure wall and slope stability during various stages of wall construction and excavation where discontinuous rows of nails will be installed (if applicable); information on space requirements for installation equipment; temporary shoring plans (if applicable); information on provisions for working in the proximity of underground facilities or utilities (if applicable).

d. Proposed nail drilling methods and equipment including drill hole diameter proposed to achieve the specified pullout resistance values and any variation of these along the wall alignment.

e. Engineered Drawings showing the proposed sequence and geometry of the wall excavation, and indicating the proposed soil nail layout, including any variation from the layout shown on the Plans. Engineered Drawings must be signed by an Ohio Registered Professional Engineer.

f. Calculations in support of the selected drill hole diameter and length; nail bar grade, diameter, and length; and all of the items in Sections 7.4 and 7.5 of this Special Provision.

2. Nail grout mix design including:

a. Type of Portland cement.

b. Aggregate source and gradation.

c. Proportions of mix by weight and water‐cement ratio.

d. Manufacturer, brand name and technical literature for proposed admixtures.

e. Compressive strength test results (per AASHTO T106/ASTM C109) supplied by a qualified independent testing lab verifying the specified minimum 3 and 28‐day grout compressive strengths. Previous test results for the proposed grout mix completed within one year of the start of grouting may be submitted for initial verification and acceptance of the required compressive strengths and start of production work.

3. Proposed nail grout placement procedures and equipment.

4. Proposed nail testing methods and equipment setup including:

a. Details of the jacking frame and appurtenant bracing.

b. Details showing methods of isolating test nails during shotcrete application (i.e., methods to prevent bonding of the soil nail bar and the shotcrete facing during testing).

c. Details showing methods of providing the temporary unbounded length and of grouting the temporary unbonded length of test nails after completion of testing.

d. Equipment list.

5. Identification number and certified calibration records for each test jack and pressure gauge and load cell to be used. Calibrate the jack and pressure gauge as a unit. In the calibration records, include the date tested, device identification number and have the calibration test results certified for an accuracy of at least 2 percent of the applied certification loads by a qualified independent testing laboratory within 90 days prior to submittal.

6. Manufacturer Certificates of Compliance for the soil nail centralizers, epoxy coating or encapsulation.

7. Certificate of Compliance for bearing nuts and plates.

The Engineer will accept or reject the Contractor’s submittals within 15 calendar days after receipt of a complete submission. The Contractor will not be allowed to begin wall construction or incorporate materials into the work until the submittal requirements are satisfied and found acceptable to the Engineer. Changes or deviations from the accepted submittals must be resubmitted for acceptance. No adjustments in contract time will be allowed due to incomplete submittals.

Upon delivery of nail bars and soil nail bar couplers (if allowed) to the project site, provide Certified mill test results for nail bars and couplers from each heat specifying the ultimate strength, yield strength, elongation and composition.

**2.5 Pre‐Construction Meeting:** A pre‐construction meeting may be scheduled by the Engineer and held prior to the start of wall construction. The Engineer, prime Contractor, and soil nail specialty Contractor shall attend the meeting. The excavation Contractor, structure foundation installation Contractor, shotcreting Contractor, and survey Contractor, if different than the prime or soil nail specialty contractor, shall also attend. The pre‐construction meeting will be conducted to clarify the construction requirements for the work, to coordinate the construction schedule and activities, and to identify contractual relationships and delineation of responsibilities amongst the prime Contractor and the various Subcontractors – particularly those pertaining to wall excavation, nail installation and testing, excavation and wall alignment survey control, and shotcrete and CIP facing construction. Soil nail wall construction requires excavation in staged lifts and excavation in the vicinity of the wall face requires special care and effort compared to general earthwork excavation.

**3.0 Definitions**

**3.1 Soil Nail:** The individual steel bar tendon with encapsulation.

**3.1.1 Hollow Bar Soil Nail (HBSN):** Hollow, steel threaded tendons that are drilled and grouted in a single operation. Grout is injected through the tendon as the drilling proceeds. The grout exits through ports that are located in a sacrificial drill bit, flushes soil cuttings out of the drill hole, and fills the annular space between the tendon and the drill hole.

**3.2 Bonded Test Length:** The length of the test nail tendon that is bonded to the ground with grout and develops adhesion during testing.

**3.3 Unbonded Test Length:** The length of the test nail tendon that is not bonded to the ground with grout and is free to elongate during testing.

**3.4 Anchorage:** The bearing plate, nut, and beveled washer that secure the concrete facing to the soil nail.

**3.5 Soil Nail Grout:** Cement grout that is injected into the drilled hole by tremie methods to cover the full length of the soil nail and provide bonding of the soil nail to the surrounding ground.

**3.6 Design Load:** The maximum load anticipated to be applied to the soil nail during its service life. For soil nail walls designed under LRFD, this is expressed as the Factored Design Load (FDL).

**3.7 Maximum Permissible Load:** The maximum permissible load is the maximum load that may be applied to the soil nail during any stage of the work. The maximum permissible load is 90 percent of the yield strength for AASHTO M31/ASTM A615 Grade 60 through Grade 100 bars, or 80 percent of the ultimate strength for ASTM A722 Grade 150 bars.

**3.8 Maximum Test Load:** The largest load applied to the soil nail when stressing during a load test. This is defined as the Verification Test Load (VTL) for pre‐production Verification Tests of sacrificial test nails, and this is defined as the Proof Test Load (PTL) for Proof Tests of production nails. The PTL is greater than or equal to the FDL.

**3.9 Alignment Load:** The load maintained on a soil nail during testing to assure that the testing equipment remains in proper position, not to exceed 2.5 percent of the maximum test load (VTL or PTL).

**3.10 Proof Test:** A soil nail load test that requires the application of defined incremental loads to the test soil nail up to the PTL and unloading of the test soil nail. The movement of the nail tendon is recorded at each load increment. At the PTL, the applied load is maintained constant for a defined time period while creep movement is recorded.

**3.11 Verification Test:** This load test requires the application of defined incremental loads to the test soil nail up to the VTL and unloading of the test soil nail. The movement of the nail tendon is recorded at each loading and unloading increment. At 0.75 VTL, the applied load is maintained constant for a defined time period while creep movement is recorded.

**3.12 Creep Movement:** The time‐dependent movements of the soil nail tendon at a constant load.

**3.13 Creep Curve:** A semi logarithmic plot of the creep movement versus time, with the units of time plotted on the logarithmic axis.

**3.14 Creep Rate:** The slope of the creep curve per log cycle of time over the final decade of the observation period.

**4.0 Materials**

Materials for soil nail structures shall consist of the following:

**4.1 Soil Nail Tendon:** AASHTO M31/ASTM A615 for Grade 60, 75, 80, or 100, or ASTM A722 for Grade 150. Deformed bar, continuous or spliced using approved bar couplers, new, straight, undamaged, bare or epoxy coated or encapsulated as shown on the Plans. Provide threading for 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. Dywidag or Williams continuous thread bars) or may be cut into a reinforcing bar. If threads are cut into a reinforcing bar, provide the next larger bar number designation at no additional cost.

**4.1.1** **Hollow Bar Soil Nail (HBSN):** Fully threaded, hollow steel tubing used as the drilling steel, grout transfer medium, and the reinforcing element of the soil nail. Tendons shall have a yield tensile strength between 60 ksi and 90 ksi. Tendons shall be new, straight, undamaged, bare, epoxy coated, galvanized, or encapsulated as shown on the Plans. The length of the threaded portion of the bar at the wall anchorage shall be as needed to allow proper attachment of the bearing plate and nut. Hollow bars shall meet the following requirements:

a. The hollow bar shall be of a fine-grained structural steel.

b. The ductility of the steel or the uniform elongation without necking shall be Agt ≥ 5%.

c. The minimum Charpy impact resistance shall be 40 Joules at -20°C per ASTM E23.

**4.1.2 HSBN Drill Bits:** Drill bits shall be selected based on the subsurface information on site and the minimum grout column required in the design. Bits require a minimum of two ports to allow grout to exit the system. Additional ports (with smaller diameters) can be used to increase grout pressure and hole diameter.

**4.2 Bar Couplers:** Couplers shall develop the full ultimate tensile strength of the bar as certified by the manufacturer. Corrosion protection to the coupler shall be provided by means of a heat shrink sleeve or heavy duty cold applied coating tape. The use of couplers shall be as stated in Section 5.8.

**4.2.1** **HBSN Couplers:** Couplers shall develop the nominal tensile capacity of the hollow bar as certified by the manufacturer and shall have a seal or a similar mechanism to ensure minimum grout loss through them. Couplers shall have a means of transferring the percussive forces when drilling, and tensile/compressive cyclic-loading forces when in service.

**4.3 Centralizers:** Centralizers shall be fabricated from Schedule 40 PVC pipe or tube, steel or other material not detrimental to the nail steel (wood shall not be used). They shall position the soil nails within 1 inch of the center of the drilled hole so as to provide a minimum required grout cover of 1 inch, allow tremie pipe insertion to the bottom of the drill hole, and allow grout to freely flow up the drill hole. Position centralizers along the soil nail so their maximum center‐to‐center spacing does not exceed 10 feet. Also locate centralizers within 1.5 feet from the top and bottom of the drill hole.

**4.4 Grout:** The cement for the grout shall be Type I, Type II, Type III, or Type V conforming to ASTM C150. The grout shall consist of a neat cement or sand/cement mixture with a minimum 3‐day compressive strength of 1,500 psi and a minimum 28‐day compressive strength of 3,000 psi per AASHTO T106/ASTM C109. Fine aggregate for the grout shall be per AASHTO M6/ASTM C33. The specific gravity of the grout shall range between 1.8 and 1.9.

**4.4.1 HBSN Grout:** The specific gravity of the grout used for drilling and installing the hollow bars may be lower than the final grout and range from 1.4 to 1.6. After the bar is installed to the desired depth, the final grout mixture shall be pumped through the hollow bar, and the nail is considered complete when the heavier mixture returns to the excavation face, signaling that the lighter drilling grout was flushed from the hole and that all drilling spoils have also been removed.

**4.4.2 HBSN Grout Mixer and Pump:** A high shear colloidal mixer with separate holding tank and water and cement dosing system should be used to ensure continuous grouting independent from mixing. Pumps should have flow rates of at least 15 gal/minute for the smaller diameter bars, and 45 gal/minute for the larger diameter bars (2 in. and above) shall be provided. A minimum of 250 psi pressure capability for sand and gravel and 1,500 psi capability should be available in clays and silts. To record the grout volume and pressure, an automated monitoring system may be used.

**4.5 Admixtures:** AASHTO M194/ASTM C494. Admixtures which 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.

**4.6 Encapsulation:** Minimum 0.04 inch thick corrugated HDPE tube conforming to AASHTO M252 or corrugated PVC tube conforming to ASTM D1784, Class 13464‐B. Encapsulation shall provide at least 0.2 inches of grout cover over the nail bar. Factory fabrication of the encapsulation is preferred. Upon the Engineer’s acceptance, the encapsulation may be field fabricated if done in strict accordance with the manufacturer’s recommendations. The encapsulation shall be:

a. Resistant to chemical attack from aggressive environments, grout, or grease.

b. Fabricated from materials nondetrimental to the prestressing steel.

c. Capable of withstanding abrasion, impact, and bending during handling and installation.

d. Free of flaws which would permit water to enter into the soil nail system.

e. Capable of transferring stresses from the grout inside the capsule to the grout outside the capsule.

f. Resistant to ultraviolet light.

**4.7 Film Protection:** Polyethylene film per AASHTO M171.

**4.8 Fusion Bonded Epoxy Coating:** ASTM A775. Minimum 0.012 inch 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.

**4.9 Bearing Plate:** The bearing plate shall conform to the requirements of 711 for Structural Steel.

**4.10 Anchorage:** The steel nut and beveled washer used in the anchorage shall be the standard product of the bar manufacturer and conform to the requirements of 711 for High-Strength Steel Bolts, Nuts, and Washers. The nut shall be hexagonal and fitted with beveled washer or spherical seat to provide uniform bearing. The anchorage shall be capable of transferring 100 percent of the guaranteed ultimate tensile strength (GUTS) from the soil nail tendon to the bearing plate.

**4.11 Shear Connectors:** Conform to C&MS Item 513.22.

**4.12 Welded Wire Fabric:** ASTM A1060.

**4.13 Reinforcing Steel:** Conform to C&MS Item 509.

**4.14 Prefabricated Geocomposite Drain (PGD):** Conform to C&MS Item 518.

**4.15 Drain Pipe:** Conform to C&MS Item 707.33.

**4.16 Low Strength Mortar (Flowable Fill):** Conform to C&MS Item 613.

**4.17 Materials Handling and Storage:** Store cement to prevent moisture degradation and partial hydration. Do not use cement that has become caked or lumpy. Store aggregates so that segregation and inclusion of foreign materials are prevented. Do not use the bottom 6 inches of aggregate piles in contact with the ground.

Store steel reinforcement on supports to keep the steel from contacting the ground. Damage to the nail steel as a result of abrasion, cuts, nicks, welds, and weld splatter shall be cause for rejection. Do not ground welding leads to nail bars. Protect nail steel from dirt, rust, and other deleterious substances prior to installation. Heavy corrosion or pitting of nails shall be cause for rejection. Light rust that has not resulted in pitting is acceptable. Place protective wrap over the anchorage end of nail bars, to which bearing plates and nuts will be attached, to protect during handling, installation, grouting and shotcreting.

Do not move or transport encapsulated nails until the encapsulation grout has reached sufficient strength to resist damage during handling. Handle encapsulated nails in a manner that will prevent large deflections, distortions or damage. Repair encapsulated nails that are damaged or defective in accordance with the manufacturer’s recommendations or remove them from the site.

Handle and store epoxy coated bars in a way that will prevent them from being damaged beyond what is permitted by ASTM 3963. Repair damaged epoxy coating in accordance with ASTM A775 and the coater’s recommendations using an epoxy field repair kit approved by the epoxy manufacturer. Repaired areas shall have a minimum 0.012 inch coating thickness.

**5.0 Construction Requirements**

**5.1 Construction Site Survey:** Before bidding the Work, the Contractor shall review the available subsurface information and visit the site to assess the site geometry, equipment access conditions, and location of existing structures and above ground facilities.

The Contractor is responsible for field locating and verifying the location of all utilities shown on the Plans prior to starting the Work. Maintain uninterrupted service for those utilities designated to remain in service throughout the Work. Notify the Engineer of any utility locations different from shown on the Plans that may require nail relocations or wall design modification. The Contractor is also responsible for field locating and verifying the location of all structure foundations adjacent to the soil nail wall, which may conflict with the soil nail locations.

Prior to start of any wall construction activity, the Contractor shall notify the Engineer and inspect the site to observe, survey, benchmark, monument and videotape the pre-construction condition of the site, existing structures and facilities. During construction, the Contractor shall observe the conditions above the soil nail wall on a daily basis for signs of ground movement in the vicinity of the wall. Immediately notify the Engineer if a sign of movements such as new cracks in structures, increased size of old cracks or separation of joints in structures, foundations, streets or paved and unpaved surfaces are observed. If the Engineer determines that the movements exceed ½ inch and require corrective action, the contractor shall take corrective actions necessary to stop the movement or perform repairs. When due to the contractor’s methods or operations or failure to follow the specified/accepted construction sequence, as determined by the Engineer, the costs of providing corrective actions will be borne by the contractor. When due to differing site conditions, as determined by the Engineer, the costs of providing corrective actions will be paid as Extra Work.

**5.2 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 acceptance 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.

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 acceptance 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 accepted 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.

**5.3 Excavation and Wall Alignment Survey Control:** Unless specified otherwise, the Contractor shall provide survey reference and control points at or offset along the top of wall alignment at approximately 30-foot intervals prior to starting wall excavation. The Contractor shall then be responsible for providing the necessary survey and alignment control during excavation of each lift, locating and drilling each drill hole 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 finished CIP 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 placement tolerances from the wall control line shown in the Plans as defined in Table 511.07-1, 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 in the Plans.

**5.4 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 accepted submittals. Construction equipment shall not be allowed on the ground above the wall during or following excavation and placement of the wall, within a distance equal to the height of the wall excavation. No excavations steeper than those shown on the Engineered Drawings or shown on the Plans will be made above or below the soil nail wall without written acceptance of the Engineer.

**5.4.1 General Roadway Excavation:** Complete clearing, grubbing, grading and excavation above and behind the wall before commencing wall excavation. Remove and stockpile any existing rock channel protection or rock slope protection for an abutment adjacent to the soil nail wall prior to beginning wall excavation. Do not stockpile material above the wall excavation. Establish the ground line behind the wall at final grade shown on the Plans prior to beginning 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. Coordinate roadway excavation with the soil nailing work. Do not perform general roadway excavation that will affect the soil nail wall until wall construction is completed.

**5.4.2 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 Contractor should take this into account during bidding. Costs associated with wall excavation, fill placement, and removal of rock channel protection or rock slope protection shall be paid for separately, under Item 503, Unclassified Excavation. The excavation for the soil nail wall shall be done under the direction of the Soil Nail Engineer. The structure excavation pay limits are shown in 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) 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.

Proceed with the wall excavation from the top down in a horizontal staged excavation lift sequence with the ground level for each lift excavated no more than 2 feet below each nail row. Do not excavate the full wall height to the final wall alignment as shown in the Plans until ready to place the reinforcing steel and shotcrete facing for the lowest excavation lift. Excavate the existing embankment in front to the soil nail wall at each stage to form a working bench to serve as a platform for the drilling equipment. The bench shall be wide enough to provide a safe working area for the drilling equipment and workers.

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 accepted 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.

At the contractor’s option, during each excavation lift, nails may be drilled and installed through a temporary stabilizing berm. The 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 shall have 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 different berm geometry 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. Sledge hammer 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 construction submittal guidelines in Section 2.4.

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. Temporarily stabilize unstable areas by means of buttressing the exposed face with an earth berm or by other methods acceptable to the Engineer. Suspend work in unstable areas until remedial measures are developed.

**5.5 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 the method of removal of face protrusions, including the 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 accepted by the Engineer. Removal of face protrusions and backfilling of voids or over‐excavation is considered incidental to the work.

The cost to remove known man-made obstructions is considered incidental to the work. The removal of drainage lines shall not extend beyond the back of the wall. The remaining portions of abandoned drainage lines are to be fully backfilled with grout. The cost to remove unanticipated man-made obstructions will be paid as Extra Work.

**5.6 Nail Installation:** Determine the required drill hole diameter(s), drilling method, grout composition and installation method necessary to achieve the nail pullout resistance(s) specified on the Plans, in accordance with the Test Nail Acceptance Criteria in Section 7.6.

The Contractor is responsible for field locating and verifying the locations of all structure foundations adjacent to the soil nail wall. Do not render the existing slope, structures, and soil nail wall excavations unstable, and do not interrupt usage of structures remaining in service; restore any excavation performed for this purpose to the condition that existed prior to the work per 107.10. Soil nails shall be spaced so they do not conflict with these foundations. Add, eliminate, or relocate nails to accommodate actual field conditions, with the acceptance of the Engineer. Cost adjustments associated with these modifications shall be made in accordance with C&MS Item 109.05, Changes and Extra Work.

The soil nail locations shown on the Plans are considered to be the minimum number of soil nails. If the Contractor determines additional soil nails are needed to construct a stable wall, the additional locations shall be shown on the shop drawings and accepted by the Engineer. The Contractor is responsible for designing, constructing, and maintaining a stable soil nail wall. The cost of any redesign, additional material, or installation modifications resulting from actions of the contractor shall be borne by the contractor.

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 accepted by the Engineer. Install verification test nails using the same equipment, methods, nail inclination and drill hole diameter as planned for the production nails. Perform pre‐production verification tests in accordance with Section 7.4 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 shall be as specified in the Plans or as accepted by the Engineer. 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 acceptance, verification test nails may also be installed at different angle orientations or locations other than those 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 acceptance, the shotcrete facing may be placed before drilling and installing the nails. Provide a blockout through the shotcrete facing at drill hole 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 drill hole 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. The cost shall be incidental to the work.

**5.7 Drilling:** The drill holes for the soil nails shall be made at the locations, orientations, and minimum lengths shown on the Plans or the Engineered Drawings or as accepted by the Engineer. Select drilling equipment and methods suitable for the ground conditions shown in the soil profile sheets and boring logs. Select drill hole 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 ½ inch grout cover over the encapsulation or encapsulated nails. 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 acceptance, 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. Where caving ground is encountered, cased drilling methods may be used to support the sides of the drill holes.

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.

**5.8 Nail Bar Installation:** Provide nail bars in accordance with the layout shown on the Plans or the Engineered Drawings. Provide centralizers sized to position the bar within 1 inch of the center of the drill hole. Position centralizers along the soil nail so their maximum center‐to‐center spacing does not exceed 10 feet. Also locate centralizers within 1.5 feet from the top and bottom of the drill hole. 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 drill hole and allow grout to flow freely up the hole.

Soil nail bars shall be continuous except in restricted areas where there is not enough room for the full nail length to be inserted into the drill hole. In these restricted areas, the Contractor shall be permitted to couple bars together to achieve the desired length. The minimum allowable bar length shall be 10 feet, with not more than two couplers per soil nail. The Contractor shall make every effort to use no couplers or only one where possible. All coupled bars shall be accepted by the Engineer prior to installation.

Inspect each nail bar before installation and repair or replace damaged bars or corrosion protection. Check uncased drill holes 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 9 inches or less.

Place a bearing plate against the reinforced shotcrete facing, over the head of the soil nail tendon protruding from the drill hole. If soil nails are installed prior to the application of the reinforced shotcrete facing, lightly press the bearing plate into the fresh shotcrete as the shotcrete starts to cure. Install a hex nut and washer to engage the nail head against the bearing plate. Wrench-tighten the hex nut within 24 hours of placing the bearing plate.

**5.8.1 HBSN Installation:** The use of couplers for HSBN is not confined to only restricted areas. As drilling, grouting, and bar insertion are performed as a single operation, drill holes are not checked for cleanliness prior to insertion of the HBSN.

**5.9 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:

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

Soil nails which 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 which encounter unanticipated obstructions during drilling shall be relocated, as accepted by the Engineer. The cost of drilling and backfilling drill holes abandoned due to unanticipated obstructions will be paid as Extra Work.

**5.10 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 CIP facing line and grade within 5 days after completion of the CIP facing.

**6.0 Grouting**

**6.1 Grout Mix Design:** Use a neat cement grout or a sand‐cement grout. Submit the proposed nail grout mix design to the Engineer for review and acceptance in accordance with the construction submittal guidelines in Section 2.4. The design mix submittal shall include compressive strength test results verifying that the proposed mix will have a minimum 3‐day compressive strength of 1,500 psi and minimum 28‐day compressive strength of 3,000 psi.

**6.2 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.

**6.3 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.

**6.4 Grouting Methods:** Grout the drill hole after installation of the nail bar. Each drill hole will be grouted within 2 hours of completion of drilling, unless otherwise accepted 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 drill hole 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 drill holes 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 drill hole 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.

**7.0 Testing**

**7.1 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 selected by the Engineer. Perform proof tests on production nails at locations selected by the Engineer. Any soil nail shall only be subjected to either a verification test or proof test but not both. Required nail test data shall be recorded by the Engineer. 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. Construct a graph showing a plot of soil nail movement versus load for each load increment and a Creep Curve plot of soil nail movement versus time for each creep test. Supply the testing data and plots of soil nail movement to the Engineer for each verification test or proof test.

**7.2 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 acceptance in accordance with the construction submittal guidelines in Section 2.4. 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.

**7.2.1 Test HBSN Unbonded Length:** Since the drilling installation of HBSNs results in a fully grouted hole, utilize one of the following three methods to provide an unbonded length for HBSN testing:

1. Following HBSN installation, remove a length of the grout within the drill hole by flushing using a tremie pipe and water.
2. Use an additional length of HBSN outside of the grouted hole as an unbonded length. In this case, offset the testing equipment from the top of the drilled hole by a distance equal to the additional unbonded length.
3. Provide a pre-installed temporary smooth casing as a bond-breaker to create an unbonded length within the drill hole.

**7.3 Testing Equipment:** Testing equipment shall include dial gauges, dial gauge support, jack, pressure gauge, electronic load cell, and a reaction frame. Provide a description of the test setup and the jack, pressure gauge, and load cell calibration curves in accordance with Section 2.4.

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 a pressure gauge. The pressure gauge shall be graduated in 100 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 inch. 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.

**7.4 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 selected by the Engineer. Perform a minimum of one verification test 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 drill hole diameter, and reaction frame dimensioning to the Engineer for acceptance in accordance with the construction submittal guidelines in Section 2.4. Construct verification test nails using the same equipment, installation methods, nail inclination, and drill hole 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 maximum permissible bar structural load during testing shall not be greater than 90 percent of the yield strength for Grade 60 through Grade 100 bars, or 80 percent of the ultimate strength for Grade 150 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 maximum bonded length for verification testing *LBVTmax* shall be determined by the following equation to avoid structurally overstressing the verification test nail bar:

*LBVTmax* = *CRT* × *At* × (*fy* or *fu*) / (*rpo*), where:

*LBVTmax* = Maximum Verification Test Nail Bonded Length (ft). If *LBVTmax* is less than 10.0 ft, then the size of the verification test nail bar shall be increased until *LBVTmax* is at least 10.0 ft.

*CRT* = reduction coefficient, 0.9 for Grade 60 to 100 bars or 0.8 for Grade 150 bars

*At* = cross-sectional area of the verification test nail bar (in2)

*fy* = nominal yield resistance of the verification test nail bar (ksi) for Grade 60 to 100 bars

*fu* = minimum ultimate tensile strength of the verification test nail bar (ksi) for Grade 150 bars

*rpo* = nominal load transfer rate (kips/ft) = (π × *qU* × *Ddh*) / 12

*qU* = nominal bond strength per unit area (ksf)

*Ddh* = drill hole diameter (in)

The Verification Test Load (VTL) during verification testing shall be determined by the following equation:

VTL = *LBVT* × *rpo* (kips/ft)

*LBVT* = Verification Test Nail Bonded Length (ft). *LBVT* shall be between 10.0 ft and *LBVTmax*.

Verification test nails shall be incrementally loaded to a maximum test load of the Verification Test Load (VTL) in accordance with the following loading schedule. The soil nail movements shall be recorded at each load increment at 1 minute, 2, 5, and 10 minutes.

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| **VERIFICATION TEST LOADING SCHEDULE** |
| **LOAD** | **HOLD TIME** |
| AL (≤ 0.025 VTL) | 1 minute |
| 0.125 VTL | 10 minutes |
| 0.250 VTL | 10 minutes |
| 0.375 VTL | 10 minutes |
| 0.500 VTL | 10 minutes |
| 0.625 VTL | 10 minutes |
| 0.750 VTL (Creep Test) | 60 minutes |
| 0.875 VTL | 10 minutes |
| 1.00 VTL (Max. Test Load) | 10 minutes |
| AL (≤ 0.025 VTL) | 1 minute |

The alignment load (AL) should be the minimum load required to align the testing apparatus and should not exceed 2.5 percent of VTL. 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 0.750 VTL 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.

At the end of the test, reduce the load back to AL, and record the permanent set of the soil nail.

**7.5 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. The locations shall be designated by the Engineer.

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. The maximum permissible bar structural load during testing shall not be greater than 90 percent of the yield strength for Grade 60 through Grade 100 bars, or 80 percent of the ultimate strength for Grade 150 bars.

The proof test bonded length *LBPT* shall not exceed *LBPTmax*, or the above minimum lengths, whichever is greater. However, production proof test nails shorter than 13 feet in length may be constructed with less than the minimum 10 feet bond length with the minimum unbonded length still limited to 3 feet. The maximum bonded length for proof testing *LBPTmax* shall be determined by the following equation to avoid structurally overstressing the proof test nail bar:

*LBPTmax* = *CRT* × *At* × (*fy* or *fu*) / (*rpo × 0.75*), where:

*LBPTmax* = Maximum Proof Test Nail Bonded Length (ft).

*CRT*, *At*, *fy*, *fu*, and *rpo* are as defined in Section 7.4.

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

PTL = *LBPT* × *rpo* (kips/ft) × 0.75 ≥ FDL

*LBPT* = Proof Test Nail Bonded Length (ft).

Proof tests shall be performed by incrementally loading the proof test nail to a maximum test load of the Proof Test Load (PTL) in accordance with the following loading schedule. The nail movement at each load increment 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 the maximum test load, the load shall be held long enough to obtain a stable reading.

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| **PROOF TEST LOADING SCHEDULE** |
| **LOAD** | **HOLD TIME** |
| AL (≤ 0.025 PTL) | Until Stable |
| 0.167 PTL | Until Stable |
| 0.333 PTL | Until Stable |
| 0.500 PTL | Until Stable |
| 0.667 PTL | Until Stable |
| 0.833 PTL | Until Stable |
| 1.00 PTL (Max. Test Load) | See Below |
| AL (≤ 0.025 PTL) | Until Stable |

The alignment load (AL) should be the minimum load required to align the testing apparatus and should not exceed 2.5 percent of PTL. 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 (PTL). 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 minute, 2, 3, 5, 6 and 10 minutes. Where the soil nail movement measured for the creep test between 1 minute and 10 minutes exceeds 0.04 inch, the maximum test load shall be maintained an additional 50 minutes and movements shall be recorded at 20 minutes, 30, 50 and 60 minutes.

At the end of the test, reduce the load back to AL, and record the permanent set of the soil nail.

**7.6 Test Nail Acceptance Criteria:** A test nail shall be considered acceptable when:

1. For verification tests, a total creep movement of less than 0.08 inches 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.

2. For proof tests, a total creep movement of less than 0.04 inches is measured between the 1 and 10 minute readings or a total creep movement of less than 0.08 inches is measured between the 6 and 60 minute readings and the creep rate is linear or decreasing throughout the creep test load hold period.

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

4. A pullout failure does not occur at PTL or before reaching VTL. 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. Alternately, with the acceptance of the Engineer, the Contractor may opt to increase the test load beyond VTL to determine pullout resistance for a verification test nail; in this event the test load shall not exceed the maximum permissible bar structural load.

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 drill hole has not collapsed during testing, (2) the minimum required drill hole 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.

**7.7 Test Nail Rejection:** If a test nail does not satisfy the acceptance criteria, it will be rejected. The Contractor shall determine the cause for the failure.

**7.8 Verification Test Nails:** The Engineer will evaluate the results of each verification test. Installation methods which 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.

**7.9 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 drill hole 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 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.

**8.0 Method of Measurement**

**8.1** Permanent Soil Nails shall be included with Item Special - Retaining Wall, Soil Nail for payment and shall include all labor, equipment, and materials necessary to complete the work. The major items included in this item are the drilling, casing, bars, grout, corrosion protection, and anchorage.

**8.2** Verification Tests shall be included with Item Special - Retaining Wall, Soil Nail Verification Test for payment and shall include all labor, equipment, and materials necessary to complete the work. Verification Tests are performed on pre‐production sacrificial test nails; costs associated with installation of the verification test nails are included with this item.

**8.3** Proof Tests shall be included with Item Special - Retaining Wall, Soil Nail Proof Test for payment and shall include all labor, equipment, and materials necessary to complete the work. Proof Tests are performed on production soil nails; costs associated with installation of the proof test nails are included with Item 530 Special - Retaining Wall, Soil Nail.

**9.0 Basis of Payment**

The Department will pay for structure excavation, wall drainage, shotcrete facing, cast-in-place facing concrete, facing reinforcing steel, and concrete sealer under separate pay items

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

**Item Unit Description**

530 Each Special - Retaining Wall, Soil Nail

530 Each Special - Retaining Wall, Soil Nail Verification Test

530 Each Special - Retaining Wall, Soil Nail Proof Test