



**SPECIAL PROVISIONS
FOR
ROCK NAILS**

Hardin County
BRFN-065-6(42)--39-42

Effective Date
July 20, 2010

THE STANDARD SPECIFICATIONS, SERIES 2009, ARE AMENDED BY THE FOLLOWING MODIFICATIONS AND ADDITIONS. THESE ARE SPECIAL PROVISIONS AND THEY SHALL PREVAIL OVER THOSE PUBLISHED IN THE STANDARD SPECIFICATIONS.

090079.01 DESCRIPTION.

This work consists of installing rock nails as part of the construction of a permanent rock nailed wall as specified herein and as shown on the plans. The Contractor shall furnish all labor, materials, and equipment required to complete the work. The Contractor shall select the excavation, drilling, and grouting methods. The diameter and length of the drillholes is shown on the plans.

The work shall include excavating in staged lifts in accordance with the approved Contractor's plan; detailing the drilling of the rock nail drillholes to the diameter and length shown on plans; grouting the nails; providing and installing the specified drainage features; providing and installing bearing plates, washers, nuts, reinforcing steel, and other required miscellaneous materials.

The Contractor shall be responsible for vibration and crack monitoring during demolition/construction activities near vulnerable structures. Refer to Special Provisions for Vibration Monitoring for requirements.

090079.02 MATERIALS.

A. ROCK NAILS

1. Nail Solid Bar:

ASTM A 722 for Grade 150. Deformed bar, continuous without splices or welds, new, straight, undamaged, bare, and epoxy-coated, as shown on the Plans. Threaded, a minimum of 6 in. on the wall anchorage end, to allow proper attachment of bearing plate and nut. Threading may be continuous spiral deformed ribbing provided by the bar deformations (continuous thread bars) or may be cut into a reinforcing bar. If threads are cut into a reinforcing bar, provide the next-larger bar number designation from that is shown on the Plans, at no additional cost.

2. Bar Coupler:

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

3. Fusion Bonded Epoxy Coating: (ASTM A 775)

Minimum 0.016 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.

B. ROCK NAIL APPURTENANCES.

1. Centralizer:

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.

2. Nail Grout:

Neat cement or sand/cement mixture with a minimum 3 day compressive strength of 2000 psi and a minimum 28 day compressive strength of 4000 psi, per AASHTO T106/ASTM C109.

3. Fine Aggregate: AASHTO M6/ASTM C33.

4. Portland Cement: AASHTO M85/ASTM C150, Type I, II, III, or V.

5. 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.

6. Film Protection: Polyethylene film per AASHTO M171.

C. BEARING PLATES, NUTS, AND WELDED STUD SHEAR CONNECTORS.

1. Bearing Plates: AASHTO M183/ASTM A36.

2. Nuts: AASHTO M291 grade B, hexagonal, fitted with beveled washer or spherical seat to provide uniform bearing.

3. Shear Connectors: Approved type listed in Materials I.M. 453.10, Appendix A.

D. WELDED WIRE FABRIC: AASHTO M55/ASTM A185 OR A497.

E. REINFORCING STEEL: AASHTO M31/ASTM A615, GRADE 60, DEFORMED.

F. GEOCOMPOSITE SHEET DRAIN.

Manufactured with a drainage core (e.g., geonet) and a drainage geotextile attached to or encapsulating the core. Drainage core to be manufactured from long chain synthetic polymers composed of at least 85 percent by mass of polypropylenes, polyester, polyamine, polyvinyl chloride, polyoleofin, or polystyrene and having a minimum compressive strength of 40 psi when tested in accordance with ASTM D 1621 Procedure A. The drainage core with the geotextile fully encapsulating the core shall have a minimum flow rate of approximately 5

gallons per minute per foot of width tested (1 liter per second per meter of width tested) in accordance with ASTM D 4716. The test conditions shall be under an applied load of 10 psi at a gradient of 1.0 after a 100 hour seating period.

G. HORIZONTAL DRAINS.

1. Pipe:

ASTM D 1785 Schedule 40 PVC solid and perforated wall; cell classification 12454-B or 12354-C, wall thickness SDR 35, with solvent weld or elastomeric joints.

2. Fittings:

ASTM D3034, Cell classification 12454-B or C, wall thickness SDR 35, with solvent or elastomeric joints.

H. SHOTCRETE.

Refer to Special Provisions for Shotcrete for requirements.

090079.03 CONTRACTOR QUALIFICATIONS.

- A.** The rock nailing contractor shall have completed at least 3 permanent rock or soil nail retaining wall projects during the past 3 years totaling at least 10,000 square feet of wall face area and at least 500 permanent soil or rock nails.
- B.** Provide a Registered Professional Engineer in the State of Iowa with experience in the construction of permanent soil or rock nail retaining walls on at least three completed projects over the past 3 years. The Contractor may not use consultants or manufacturer's representatives to meet the requirements of this section. Provide on-site supervisors and drill operators with experience installing permanent rock or soil nails on at least three projects over the past 3 years.

090079.04 SUBMITTALS.

- A.** The Contractor shall submit a brief description of at least three projects, including the owning agency's name, address, and current phone number; location of project; project contract value; and scheduled completion date and actual completion date for the project.
- B.** At least 60 calendar days before starting rock nail work, identify the rock nail Contractor's engineer, on-site supervisors, and drill operators assigned to the project, and submit a summary of each individual's experience. Only those individuals designated as meeting the qualifications requirements shall be used for the project. The Contractor cannot substitute for any of these individuals without written approval of the Engineer. The Engineer shall approve or reject the Contractor qualifications and staff within 15 working days after receipt of the submission. Work shall not be started on any rock nail wall nor materials ordered until the Contractor's qualifications have been approved by the Engineer. The Engineer may suspend the work if the Contractor substitutes unqualified personnel for approved personnel during construction. If work is suspended due to the substitution of unqualified personnel, the Contractor shall be fully liable for additional costs resulting from the suspension of work and no adjustment in contract time resulting from the suspension of the work will be allowed.
- C.** The Contractor is responsible for providing the necessary survey and alignment control during the excavation for each lift, locating drillholes and verifying limits of wall installation. At least 30 days before starting rock nail work, submit a Construction Plan to the Engineer that includes the following.
 - 1.** The start date and proposed detailed wall construction sequence.

2. Drilling and grouting methods and equipment.
 3. Nail grout mix design, including compressive strength test results (per AASHTO T106/ASTM C109) supplied by a qualified independent testing lab verifying the specified minimum 3 day and 28 day grout compressive strengths. Previous test results for the same grout mix completed within one year of the start of grouting may be submitted for verification of the required compressive strengths.
 4. Nail grout placement procedures and equipment.
 5. Temporary shotcrete materials and methods.
 6. Rock nail testing methods and equipment setup.
 7. Identification number and certified calibration records for each test jack and pressure gauge and load cell to be used. Jack and pressure gauge shall be calibrated as a unit. Calibration records shall include the date tested, the device identification number, and the calibration test results and shall be certified for an accuracy of at least 2 percent of the applied certification loads by a qualified independent testing laboratory within 90 days prior to submittal.
 8. Manufacturer Certificates of Compliance for the rock nail ultimate strength, nail bar steel, Portland cement, centralizers, bearing plates and epoxy coating.
- D. The Engineer shall approve or reject the Contractor's Construction Plan within 30 working days after the submission. Approval of the Construction Plan does not relieve the Contractor of his responsibility for the successful completion of the work.

090079.05 STORAGE AND HANDLING.

Store and handle rock nail bars in a manner to avoid damage or corrosion. Replace bars exhibiting abrasions, cuts, welds, weld splatter, corrosion, or pitting. Repair or replace any bars exhibiting damage to encapsulation or epoxy coating. Repaired epoxy coating areas shall have a minimum 0.012 inch thick coating.

090079.06 EXCAVATION.

- A. The height of exposed unsupported final excavation face cut 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 apply 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 demonstrate that the delay will not adversely affect the excavation face stability.
- B. Excavation of the next-lower lift shall not proceed until nail installation, reinforced shotcrete placement, attachment of bearing plates and nuts, and nail testing have 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.

090079.07 NAIL INSTALLATION.

Provide nail length and drillhole diameter as shown in the plans. Drill holes for the rock nails at the locations, elevations, orientations, and lengths shown on the Plans. Select drilling equipment and methods suitable for the ground conditions and in accordance with the accepted installation methods submitted by the Contractor. The use of drilling muds or other fluids to remove cuttings will not be allowed. If caving ground is encountered, use cased drilling methods to support the sides of the drillholes. The use of self-drilling nail bars (also known as hollow, self-grouting or pressuregrouted

nail bars) will not be allowed. Provide nail bars as shown 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 that their maximum center-to-center spacing does not exceed 8 feet. Also locate centralizers within 1.5 feet from the top and bottom of the drillhole.

090079.08 GROUTING.

- A. Grout the drillhole after installation of the nail bar and within 2 hours of completion of drilling. Inject the grout at the lowest point of each drillhole through a grout tube, casing, hollow-stem auger, or drill rods. Keep the outlet end of the conduit delivering 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.
- B. Test nail grout according to AASHTO T106/ASTM C109 at a frequency of one test per mix design and a minimum of one test for every 52 cubic yards of grout placed. Provide grout cube test results to the Engineer within 24 hours of testing.
- C. Grouting shall be performed in accordance with ACI 306R during periods of cold weather.

090079.09 NAIL TESTING.

- A. Perform both verification and proof testing of designated test nails. Perform verification tests on sacrificial test nails at locations shown on the Plans. Perform proof tests on production nails at locations selected by the Engineer. Testing of any nail shall not be performed until the nail grout and shotcrete facing have cured for at least 72 hours or attained at least their specified 3 day compressive strength.
- B. Testing equipment shall include two dial gauges, dial gauge support, jack and pressure gauge, electronic load cell, and a reaction frame. The pressure gauge shall be graduated in 75 psi increments or less. Measure the nail head movement with a minimum of two dial gauges capable of measuring to 0.001 inch.

090079.10 VERIFICATION TESTING OF SACRIFICIAL NAILS.

- A. Perform verification testing prior to installation of production nails to confirm the appropriateness of the Contractor's drilling and installation methods, and verify the required nail pullout resistance.
- B. Verification test nails shall have both bonded and unbonded lengths. Along the unbonded length, the nail bar is not grouted. The unbonded length of the test nails shall be at least 3 feet. The bonded length of the rock nail during verification tests, L_{BVT} , shall be at least 10 feet but not longer than a maximum length, L_{BVTmax} , such that the nail load does not exceed 90% of the nail bar tensile allowable load during the verification test. Therefore, the following requirements shall be met:

$$L_{BVT} \leq \begin{cases} 10 \text{ ft} \\ L_{BVTmax} \end{cases}$$

The length L_{BVTmax} is defined as:

$$L_{BVTmax} = \frac{C_{RT} \times A_t \times f_y}{Q_{ALL} \times FS_{T \text{ ver}}}$$

where,

- C_{RT} = Reduction coefficient. Use $C_{RT} = 0.9$ for Grade 75 bars.
- A_t = Nail bar cross-sectional area;
- f_y = Nail bar yield tensile strength;
- Q_{ALL} = Allowable pullout resistance per unit length ($Q_{ALL} = Q_u/FSP$), as specified herein or in plans; and
- FS_{Tver} = Factor of safety against tensile failure during verification tests (use 2.5 or, preferably, 3).

The maximum bonded length shall be preferably based on production nail maximum bar grade. Provide larger bar sizes, if required, to meet the 10 feet minimum test bonded length requirement at no additional cost.

The Design Test Load (DTL) shall be determined as follows:

$$DTL = L_{BVT} \times Q_{ALL}$$

DTL shall be calculated based on as-built bonded lengths.

- C. Perform verification tests by incrementally loading the verification test nails to failure or a maximum test load of 300 percent of the DTL in accordance with the following loading schedule. Record the rock nail movements at each load increment.

Verification Test Loading Schedule.

Load	Hold Time
0.05 DTL max.(AL)	1 minute
0.25 DTL	10 minutes
0.50 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	10 minutes
2.50 DTL.	10 minutes max
3.0 DTL or Failure.	10 minutes max
0.05 DTL max. (AL)	1 minute (record permanent set)

The alignment load (AL) should be the minimum load required to align the testing apparatus and should not exceed 5 percent of the DTL. Dial gauges should be set to “zero” after the alignment load has been applied. Following application of the maximum load (3.0 DTL) reduce the load to the alignment load (0.05 DTL maximum) and record the permanent set.

- D. Hold each load increment for at least 10 minutes. Monitor the verification test nail for creep at the 1.50 DTL load increment. Measure and record nail movements during the creep portion of the test in increments of 1, 2, 3, 5, 6, 10, 20, 30, 50, and 60 minutes. Maintain the load during the creep test within 2 percent of the intended load by use of the load cell.

090079.11 PROOF TESTING OF PRODUCTION NAILS.

- A. Perform successful proof testing on nails as shown on the Micropile Retaining Wall and Rock-Cut Support Walls Design Sheets for this project. The contractor may propose alternate testing patterns. The Engineer shall determine the locations and number of proof tests prior to nail installation in each row. Production proof test nails shall have both bonded

and temporary unbonded lengths. The temporary unbonded length of the test nail shall be at least 3 feet. The bonded length of the rock nail during proof production tests, L_{BPT} , shall be the least of 10 feet and a maximum length, $L_{BPT\ max}$, such that the nail load does not exceed 90% of an allowable value of the nail bar tensile load during the proof production test. Therefore, the following requirements shall be met:

$$L_{BPT} \leq \begin{cases} 10 \text{ ft} \\ L_{BVT\ max} \end{cases}$$

The length $L_{BPT\ max}$ is defined as:

$$L_{BPT\ max} = \frac{C_{RT} \times A_t \times f_Y}{Q_{ALL} \times FS_{T\ proof}}$$

where,

- C_{RT} = Reduction coefficient. Use 0.9 Grade 75 bars
- A_t = Nail bar cross-sectional area
- f_Y = Nail bar yield tensile strength
- Q_{ALL} = Allowable pullout resistance per unit length ($Q_{ALL} = Q_u/FSP$), as specified herein or in plans, and
- $FS_{T\ proof}$ = Factor of safety against tensile failure during proof production tests (use 1.5)

The maximum bonded length shall be based on production nail maximum bar grade. Production proof test nails shorter than 12 feet in length may be constructed with less than the minimum 10 feet bond length.

The Design Test Load (DTL) shall be determined as follows:

$$DTL = L_{BPT} \times Q_{ALL}$$

DTL shall be calculated based on as-built bonded lengths.

- B.** Perform proof tests by incrementally loading the proof test nail to 150 percent of the DTL in accordance with the following loading schedule. Record the rock nail movements at each load increment.

Proof Test Loading Schedule.

Load	Hold Time
0.05 DTL max. (AL)	Until Movement Stabilizes
0.25 DTL	Until Movement Stabilizes
0.50 DTL	Until Movement Stabilizes
0.75 DTL	Until Movement Stabilizes
1.00 DTL	Until Movement Stabilizes
1.25 DTL	Until Movement Stabilizes
1.50 DTL (Max. Test Load)	Creep Test (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 DTL. Dial gauges should be set to “zero” after the alignment load has been applied.

- C.** The creep period shall start as soon as the maximum test load (1.50 DTL) is applied and the nail movement shall be measured and recorded at 1, 2, 3, 5, 6, and 10 minutes. Where the nail movement between 1 minute and 10 minutes exceeds 0.04 inch, maintain the maximum test load for an additional 50 minutes and record movements at 20, 30, 50, and 60 minutes. Maintain all load increments within 5 percent of the intended load.

090079.12 TEST NAIL ACCEPTANCE CRITERIA.

- A. A test nail shall be considered acceptable when all of the following criteria are met:
1. For verification tests, the total creep movement is less than 0.08 inch between the 6 and 60 minute readings and the creep rate is linear or decreasing throughout the creep test load hold period.
 2. For proof tests, the total creep movement is less than 0.04 inch during the 10 minute readings or the total creep movement is less than 0.08 inch during the 60 minute readings and the creep rate is linear or decreasing throughout the creep test load hold period.
 3. For verification and proof tests, 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 2.5 DTL under verification testing and 1.5 DTL test load under proof testing. Pullout failure is defined as the inability to further increase the test load while there is continued pullout movement of the test nail. Record the pullout failure load as part of the test data.
- B. Maintaining stability of 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.

090079.13 TEST NAIL REJECTION.

If a test nail does not satisfy the acceptance criterion:

- A. For 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.
- B. For 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. 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.

090079.14 WALL DRAINAGE NETWORK.

Install and secure all elements of the wall drainage network as shown on the Plans. The drainage network shall consist of installing geocomposite drain strips, PVC connection pipes, wall footing drains, and weepholes as shown on the Plans. Exclusive of the wall footing drains, all elements of the drainage network shall be installed prior to shotcreting.

A. Geocomposite Drain Strips:

Install geocomposite drain strips centered between the columns of nails as shown on the Plans. The drain strips shall be at least 24 inches wide and placed with the geotextile side against the ground. Secure the strips to the excavation face and prevent shotcrete from contaminating the geotextile. Drain strips will be vertically continuous. Make splices with a 12 inch minimum overlap such that the flow of water is not impeded. Install drain plate and connector pipe at base of each strip. Repair damage to the geocomposite drain strip, which may interrupt the flow of water.

B. Footing Drains:

If applicable, install footing drains at the bottom of each wall as shown on the Plans. The drainage geotextile shall envelope the footing drain aggregate and pipe and conform to the dimensions of the trench. Overlap the drainage geotextile on top of the drainage aggregate as shown on the Plans. Replace or repair damaged or defective drainage geotextile.

090079.15 SHOTCRETE FACING.

Provide construction shotcrete facing and permanent shotcrete facing (if required) in accordance with the plans. Where shotcrete is used to complete the top ungrouted zone of the nail drill hole near the face, position the nozzle into the mouth of the drill hole to completely fill the void.

A. Final Face Finish:

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

B. Attachment of Nail Head Bearing Plate and Nut:

Attach a bearing plate, washers, and nut to each nail head as shown on the Plans. While the shotcrete construction facing is still plastic and before its initial set, uniformly seat the plate on the shotcrete by hand-wrench tightening the nut. Where uniform contact between the plate and the shotcrete cannot be provided, set the plate in a bed of grout. After grout has set for 24 hours, hand-wrench tighten the nut. Ensure bearing plates with headed studs are located within the tolerances shown on the plans.

C. Tolerances:

Construction tolerances for the shotcrete facing from plan location and plan dimensions are as follows:

Horizontal location of reinforcing bars and headed studs:	0.4 inch
Location of headed studs on bearing plate:	1/4 inch
Spacing between reinforcing bars:	1 inch
Reinforcing lap, from specified dimension:	1 inch
Nail head bearing plate deviation from parallel to wall face:	10 degrees

090079.16 REINFORCING STEEL.

Submit all order lists and bending diagrams, fabricate reinforcing steel, ship and protect material, place, fasten, and splice reinforcing steel according to ACI Standard.

090079.17 BACKFILLING BEHIND WALL FACING UPPER CANTILEVER.

- A.** Compact backfill within 3 feet behind the wall facing upper cantilever using light mechanical tampers.
- B.** Backfill shall be relatively free draining granular material.

090079.18 ACCEPTANCE.

Material for the rock nail retaining wall will be accepted based on the manufacturer production certification or from production records. Construction of the rock nail retaining wall will be accepted based on visual inspection and the relevant production testing records.

090079.19 METHOD OF MEASUREMENT.

Rock nails will be measured in linear feet of production rock nails installed. The length to be paid will be the length measured along the nail 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 or verification test nails, which shall be considered incidental to production nail installation. Failed verification test nails or additional verification test nails installed to verify alternative nail installation methods proposed by the Contractor will not be measured.

090079.20 BASIS OF PAYMENT.

The accepted quantities of Rock Nails will be paid for at the contract unit price per linear foot of production rock nails installed.

The contract unit price will be full compensation for providing all design, materials including but not limited to epoxy coated rock nails/solid bars, centralizers, grout, bearing plates, shear studs/anchor plates, washers, nuts, and reinforcing bars/walers, labor, equipment, verification and proof tests, and incidentals to install the rock nails in accordance with all requirements of this specification and the contract. The welded wire mesh, pre-fabricated drainage mats, horizontal drains, and concrete fascia will be paid for separately.