

ROCK BLASTING:

(SPECIAL)

Description

This project special provision governs fracturing rock for excavation and constructing stable rock cut slopes using controlled, production and trench blasting. Controlled blasting is used to form a certain slope by limiting the effects of blasting with cushion or trim blasting. Another type of controlled blasting known as presplitting is not addressed by this provision. Production blasting is used to fracture rock in manageable sizes for excavation. Trench blasting is used to create trenches in rock for utilities and pipes and construct open ditches. This provision also addresses secondary blasting and blasting adjacent to highway structures in lieu of Article 410-11 of the *Standard Specifications*.

Exercise care when using bulk ammonium nitrate and fuel oil (ANFO) near open water to prevent ANFO from leaching into lakes, streams, creeks and rivers. Control blasting to avoid damaging public and private property. Contain flyrock in the construction limits or perform blasting such that no flyrock occurs if required in the "Project Requirements" section of this provision. When blasting in the vicinity of an open travelway, have equipment standing by to remove material that interferes with traffic flow.

Perform rock blasting, develop blast plans, provide explosive materials, drill, load and stem holes, record drilling, conduct blast surveys, monitor blasts and submit drilling records, surveys and reports in accordance with the contract and accepted submittals.

Project Requirements

At a minimum, conduct pre-blast surveys for any building, residence or utility when the maximum charge per delay (W_{max}) and the distance to the subject structure (D) may result in a peak particle velocity (PPV) equal to or greater than 0.4 in/sec (10 mm/sec) using the formulas in the "Peak Particle Velocity and Scaled Distance" section of this provision.

Blasting is subject to the "USBM Alternative Blasting Level Criteria" from the ISEE Blasters' Handbook, 17th Edition for not-to-exceed limits. Warning levels for vibration are 0.25 in/sec (6 mm/sec) less than the not-to-exceed limits. For air-overpressure (noise), blasting is subject to a not-to-exceed limit of 133 dBL and a warning level of 120 dBL.

Definitions

Air-Overpressure or Air Blast (Noise) – The pulsating pressure changes above and below ambient air pressure generated by an explosion. Air-overpressure "linear scale" measurements include low frequency noise with a 2 hertz (Hz) response and are expressed in units of decibels-L (dBL).

Blast Pattern – A plan of blast hole locations or an expression of the burden and spacing distance and their relationship to each other.

Burden – The amount of rock broken by an explosive charge measured as the distance between the blast hole and the nearest free face.

Charge per Delay (W) – The sum of all charge weights firing within any 8 milliseconds (ms) time period. For example, if two 10 lb (4.5 kg) charges fire at 100 ms and one 15 lb (6.8 kg) charge fires at 105 ms, the charge per delay would be 35 lbs (15.8 kg).

Cushion or Trim Blasting – A controlled blasting technique in which a line of blast holes along a rock face are detonated during the last delay period of the blast. The main burden is moved from the face by production blast holes leaving only a small burden to be removed by the line of blast holes at the face. Charges in these holes are lighter than charges in the production blast holes.

Deck Loading (Decking) – A method of loading blast holes in which two or more explosive charges, called decks or deck charges, are loaded in the same hole separated by stemming or an air cushion.

Delay Blasting – The practice of initiating individual explosive decks, blast holes or rows of holes at predetermined time intervals using delays or delay detonators as compared to firing all blast holes simultaneously.

Flyrock – Rocks propelled through the air by the force of an explosion.

Free Face – A rock surface exposed to air or water that provides room for expansion upon fragmentation.

Magazine – Any building, structure or container, approved for storage of explosive materials other than an explosive manufacturing building.

Misfire – An event where all or some charges in a blast fail (do not detonate) when initiated or a term for any portion of explosive materials that fail to detonate as planned.

Peak Particle Velocity (PPV) – The maximum ground vibration velocity measured in the vertical, longitudinal or transverse direction. PPV measurement units are expressed in inches or millimeters per second (in/sec or mm/sec).

Scaled Distance (Ds) – A calculated value in units of $\text{ft}/\text{lb}^{0.5}$ ($\text{m}/\text{kg}^{0.5}$) describing relative vibration energy based on distance to a structure (D) and charge per delay (W). Ds is equal to D divided by the square root of W, $D_s = D / W^{0.5}$ or $W = (D / D_s)^2$.

Spacing – The distance between blast holes in a row. In production blasting, the distance is measured parallel to the free face and perpendicular to the burden.

Stemming – Crushed stone placed in the unloaded collar area of blast holes for the purpose of confining explosive charges and limiting rock movement and air-overpressure.

Subdrilling – The portion of a blast hole that is drilled below or beyond the desired excavation depth or limit. Subdrilling is generally required to prevent the occurrence of high or tight areas of unfractured rock between blast holes.

Regulations

Comply with all the latest applicable Federal, State and local codes, laws, rules and regulations as well as professional society standards for the storage, transportation and use of explosives. These include but are not limited to the following:

- The Occupational Safety and Health (OSH) Act of 1970 and the Construction Safety Act (CSA) of 1969, as amended

- Safe Explosives Act, Title XI, Subtitle C of Public Law 107-296; Interim Final Rule
- Title 29, U. S. Code, Section 651 et seq., including safety and health regulations for construction
- Title 27, Code of Federal Regulations (27 CFR), Part 555, U. S. Department of Justice, Bureau of Alcohol, Tobacco, Firearms and Explosives (ATF)
- Organized Crime Control Act of 1970, Title XI, Public Law 91-452, as amended
- Title 49, Code of Federal Regulations (49 CFR), Parts 105-177 (DOT RSPA) & Parts 301-399 (DOT FHA)
- Title 29, Code of Federal Regulations (29 CFR), Parts 1910 & 1926, N. C. Department of Labor, Division of Occupational Safety and Health
- The Mining Act of 1971, North Carolina General Statute, Chapter 74, Article 7, as amended
- Fire Code of North Carolina, Section 105.6.15 Explosives
- Administrative Rules, 13 NCAC 06.0521 – 13 NCAC 06.0526, N. C. Department of Labor
- “A Guide to the Safe Storage of Explosive Materials” and “North Carolina Occupational Safety and Health Standards in Construction for Blasting & Use of Explosives”, N. C. Department of Labor

Keep a copy of all regulations listed above at the project site.

Non-regulatory Industry Support Organizations:

- Blast Monitoring Equipment Operation Standards (1999), Vibration Subcommittee of the International Society of Explosive Engineers (ISEE)
- Institute of Makers of Explosives (IME) Safety Library Publications (SLPs)

In case of conflict, the more stringent regulation applies.

Submittals

In lieu of a blasting plan in accordance with Article 107-11 of the *Standard Specifications*, the following submittals are required for rock blasting.

- Blasting Contractor Personnel and Experience including Blasting Consultant, if applicable
- General Blast Plan including Blast Monitoring Consultant, if applicable
- Site Specific Blast Plans including Pre-blast Surveys
- Post-blast Reports including Drilling Records, Blast Monitoring Report and Blast Damage Report, when necessary

For the site specific blast plans and post-blast reports, submit two hard copies of each to the Resident Engineer. After completing all blasting for a cut, structure or an excavation, submit electronic copies (PDF on CD or DVD) of all site specific blast plans and post-blast reports.

Allow 30 calendar days upon receipt by the Department for the review and acceptance of the Blasting Contractor personnel and experience and general blast plan. Provide these submittals in both electronic and hard copy form in accordance with the following:

Submit one hard copy to the Resident Engineer. At the same time, submit a second hard copy and an electronic copy (PDF on CD or DVD) directly to the Geotechnical Engineering Unit at the following addresses:

For projects in Divisions 1-7, use the following Eastern Regional Office addresses:

Via US mail:
 Eastern Regional Geotechnical Manager
 North Carolina Department of
 Transportation
 Geotechnical Engineering Unit
 Eastern Regional Office
 1570 Mail Service Center
 Raleigh, NC 27699-1570

Via other delivery service:
 Eastern Regional Geotechnical Manager
 North Carolina Department of
 Transportation
 Geotechnical Engineering Unit
 Eastern Regional Office
 3301 Jones Sausage Road, Suite 100
 Garner, NC 27529

For projects in Divisions 8-14, use the following Western Regional Office addresses:

Via US mail:
 Western Regional Geotechnical Manager
 North Carolina Department of
 Transportation
 Geotechnical Engineering Unit
 Western Regional Office
 5253 Z Max Boulevard
 Harrisburg, NC 28075

Via other delivery service:
 Western Region Geotechnical Manager
 North Carolina Department of
 Transportation
 Geotechnical Engineering Unit
 Western Regional Office
 5253 Z Max Boulevard
 Harrisburg, NC 28075

The Engineer may suspend blasting operations in accordance with Article 108-7 of the *Standard Specifications* if submittals are illegible, incomplete or not provided.

(A) Blasting Contractor Personnel and Experience

The Engineer may waive this submittal if a Blasting Consultant is not required and the Blasting Contractor and Blaster-in-Charge for this project were previously accepted within the last year for another NCDOT project with subsurface conditions and blasting of a scope and complexity similar to that anticipated for this project.

Obtain acceptance of the Blasting Contractor personnel and experience before submitting a general blast plan.

(1) Blasting Contractor

Use a Blasting Contractor prequalified by the NCDOT Contractual Services Unit for rock blasting work (work code 070). Submit documentation that the Blasting Contractor has successfully completed at least 5 blasting projects within the last 3 years with subsurface conditions and blasting of a scope and complexity similar to that anticipated for this project. Documentation should include the General Contractor and Owner's name and current contact information with descriptions of each past project.

(2) Blaster-in-Charge

The Blaster-in-Charge has total authority over the handling, use and security of explosives and is responsible for coordinating, planning and supervising explosives use. The Blaster-in-Charge is also responsible for designing blasts and preparing blast plans when a Blasting Consultant is not required and for monitoring blasts when a Blast Monitoring Consultant is not required. Either the Blaster-in-Charge or an alternate Blaster-in-Charge is required to be on-site during blasting.

Provide verification of employment with the Blasting Contractor for the Blaster-in-Charge and any alternate Blasters-in-Charge assigned to this project. Submit documentation that each Blaster-in-Charge has a minimum of 5 years experience in blasting with past projects of scope and complexity similar to that anticipated for this project. Documentation should include resumes, references, certifications, project lists, experience descriptions and details, etc. If there is a change in the Blaster-in-Charge, discontinue explosives use until a new Blaster-in-Charge is submitted and accepted.

(3) Blasting Consultant

When a Blasting Consultant is required in the "Project Requirements" section of this provision, submit an independent consultant to design blasts and prepare blast plans. Employees of the Contractor, any affiliated companies or product suppliers are not allowed to be independent consultants. Use a Blasting Consultant approved as a Geotechnical Engineer (key person) for a consultant prequalified by the NCDOT Contractual Services Unit for the rock blasting evaluation & design discipline.

(B) Blast Plans

Blast plans are required to be signed by the Blaster-in-Charge (and Blasting Consultant, if applicable). Review and acceptance of blast plans does not relieve the Contractor of responsibility for the blast results or liability in accordance with Articles 107-11 and 107-12 of the *Standard Specifications*.

(1) General Blast Plan

Submit a general blast plan before beginning drilling, when revised drilling or blasting methods are proposed or as directed by the Engineer. At a minimum, include the following in the plan:

- Work procedures and safety precautions for the storage, transportation, handling and detonation of explosives
- Explosive products and devices for dry and wet blast holes including explosives, primers and detonators with material safety data sheets
- Drilling equipment and methods for maintaining blast hole alignment
- Typical plan, profile and sectional views for both production and controlled blasting showing hole diameter, depth, inclination and spacing, maximum blast limits, burden, subdrill depth and maximum charge per delay
- Initiation and delay methods and delay times
- Site specific blast plan format
- Blast hole drill log format
- Pre-blast survey criteria and method
- Blast monitoring report format and equipment including calibration information
- Post-blast report format
- Blast Monitoring Consultant, if applicable
- Test blast locations when required

Do not deliver explosives to the project site until the general blast plan is reviewed and accepted.

(2) Site Specific Blast Plan

After the general blast plan is accepted, submit a site specific blast plan at least 24 hours in advance of each blast. Site specific blast plans may be waived for non-critical blasts as determined by the Engineer. The following is required for the plan:

- Scaled drawings of the blast area with cross-sections showing the beginning and ending stations, hole diameter, depth, inclination, spacing, burden, subdrill depth and free face location and any joints, bedding planes, weathered zones, voids or other significant rock structure that may influence the blast
- A loading pattern diagram showing the location and amount of each type of explosive including primers and detonators
- The locations and depths of stemming, column heights and maximum charge per delay for each type of loading
- A delay and initiation diagram showing delay pattern, sequence and times
- Pre-blast surveys (once per structure; not required when submitted for a prior blast)

For site specific blast plans do not exceed the maximum charge per delay accepted in the general blast plan or submit a revised general blast plan to increase the maximum charge per delay allowed.

(C) Pre-blast Surveys and Post-blast Reports

(1) Blast Monitoring Consultant

When a Blast Monitoring Consultant is required in the “Project Requirements” section of this provision, use an independent consultant prequalified by the NCDOT Contractual Services Unit for vibration & noise monitoring work (work code 3120). Employees of the Contractor, any affiliated companies or product suppliers are not allowed to be independent consultants.

(2) Peak Particle Velocity and Scaled Distance

Use the following formulas to determine peak particle velocity (PPV) and scaled distance (Ds).

$$PPV = K(Ds)^m \quad \text{and} \quad Ds = D / (W_{max})^{0.5}$$

where: PPV = Peak Particle Velocity (in/sec or mm/sec)
 K and m = Site specific constants defining initial energy and decay
 Ds = Scaled Distance (ft/lb^{0.5} or m/kg^{0.5})
 D = Distance to subject structure (ft or m)
 W_{max} = Maximum charge per delay (lbs or kg)

Typically, a K of 240 (1725 for metric units) and an m of -1.6 may be used for the equations above. However, K and m are site specific and may be determined by performing a regression analysis of multiple PPV and Ds data pairs. Select K and m based on actual site conditions, rock type and structure, subsurface information and blast monitoring measurements.

(3) Pre-blast Survey

Conduct pre-blast surveys in accordance with the “Project Requirements” section of this provision and the accepted general blast plan. At a minimum, include the following in the survey:

- Summary naming the person who performed the survey and comments about each structure and existing condition
- Sketches of interior and exterior walls and foundations with existing cracks and a written description of the cracks including the length, width, type and angle
- 4 x 6 inch (100 x 150 mm) color 35-mm or 5-megapixel digital photographs or miniDV or DVD digital video documenting the existing cracks and condition of each structure

Submit pre-blast surveys with site specific blast plans.

(4) Post-blast Report

Within 3 days after each blast or before the next blast, whichever is sooner, submit a post-blast report signed by the Blaster-in-Charge that includes the following:

- Results and effectiveness of the blast and any proposed changes to subsequent site specific blast plans
- Blast monitoring report
- Blast damage report when necessary
- Drilling records including blast pattern and blast hole drill logs

(a) Blast Monitoring

At a minimum, monitor vibration and air-overpressure (noise) at the nearest building, residence or utility and the nearest building, residence or utility in the direction of the blast in accordance with the accepted general blast plan. Furnish seismographs capable of measuring particle velocities in the longitudinal, vertical and horizontal directions. Use monitoring equipment calibrated within one year of the date the data is collected. Interpret the recorded data and submit a blast monitoring report signed by the Blaster-in-Charge (or Blast Monitoring Consultant, if applicable) with the post-blast report that includes the following for each monitoring location:

- Type, identification and specific location of monitoring equipment
- Distance and direction to blast
- PPV in each direction and peak vector sum
- Maximum air-overpressure

If damage occurs from blasting, notify the Engineer immediately. Submit a blast damage report signed by the Blaster-in-Charge (and Blast Monitoring Consultant, if applicable) with the post-blast report that includes the following:

- Property owner's (and injured person's, if any) names, addresses and telephone numbers
- Details and description of property damage (and injury, if any) with photos or video
- Any associated tort claims, complaint letters and other applicable information

(b) Drilling Records

Identify each blast hole with a number on a blast pattern. Log the hole number, total depth, date drilled and the depth and description of significant conditions encountered such as water, voids and weak or jointed seams. Submit the blast pattern and blast hole drill logs signed by the Driller with the post-blast report.

Blast Design Requirements

(A) Vibration and Air-overpressure

Design blasts for the vibration and air-overpressure (noise) warning levels and not-to-exceed limits in the “Project Requirements” section of this provision. If warning levels are exceeded, the Engineer may require additional monitoring and the Contractor should be aware that future blasts could exceed the not-to-exceed limits. If not-to-exceed limits are exceeded, the Engineer may suspend blasting operations in accordance with Article 108-7 of the *Standard Specifications* and require test blasts and a revised general blast plan.

(B) Production Blasts

Design production blasts in accordance with the following unless otherwise approved:

- Maintain a minimum 6 ft (1.8 m) clearance between the production blast holes and final cut slope face
- Diameter of production blast holes may not exceed 6” (150 mm)
- Do not drill production blast holes below the bottom of adjacent controlled blast holes
- Use delay blasting to detonate production blast holes towards a free face

(C) Controlled Blasts

Controlled blasts are required for final cut slopes steeper than 2:1 (H:V) when the height of the rock face exceeds 15 ft (4.6 m).

(1) Cushion Blasts

Cushion blasts refer to either trim or cushion blasting. Design cushion blasts in accordance with the following unless otherwise approved:

- Diameter of cushion blast holes may not exceed 6” (150 mm)
- Minimize subdrilling to only that required for excavation of the final cut slopes
- Do not subdrill below final grade
- Bench height or lift thickness may not exceed 25 ft (7.6 m)
- Use a maximum of half the charge density and burden of the production blast holes for the cushion blast holes
- Do not use bulk ANFO or any other bulk loaded products
- Fire cushion blast holes after production blast holes with a minimum 25 ms delay

(D) Trench Blasts

Design trench blasts in accordance with the following unless otherwise approved:

- Diameter of trench blast holes may not exceed 3” (75 mm)
- Do not use bulk ANFO or any other bulk loaded products

- Use cartridge explosives or other types of explosives specifically designed for trench blasting
- Use a charge diameter $\frac{1}{2}$ to $\frac{3}{4}$ inch (13 to 19 mm) less than the diameter of the trench blast holes

Test Blasts

A test blast is defined as drilling, blasting and excavation of a test section before beginning or restarting full scale blasting. When a test blast is required in the “Project Requirements” section of this provision or as directed by the Engineer, perform one or more test blasts for both production and controlled blasting (cushion or trim blasting) or trench blasting before beginning full scale blasting. Submit proposed test blast locations with the general blast plan. Also, if the Engineer suspends blasting operations after full scale blasting has begun, one or more test blasts may be required before resuming blasting. When this occurs, inform the Engineer of the test blast locations before submitting any site specific blast plans.

Perform test blasts in accordance with the submittal, blast design and construction requirements except submit site specific blast plans for test blasts 72 hours before beginning drilling. Full scale blasting may not begin or resume until the test blasts are acceptable to the Engineer. The Engineer will not consider whether a test blast is acceptable until the rock face is exposed and the post-blast report is submitted. Examples of results that may be unacceptable include excessive vibration, air-overpressure or flyrock, overbreakage, damage to the final cut slope face and overhangs.

Construction Methods

Before beginning drilling, conduct a pre-blast meeting to discuss the blasting and monitoring. Schedule this meeting after all blast plans have been accepted. The Resident Engineer, Roadway Construction Engineer, Geotechnical Operations Engineer, Contractor and Blaster-in-Charge (and Blasting Consultant and Blast Monitoring Consultant, if applicable) will attend this pre-blast meeting.

Drill and blast in accordance with site specific blast plans, the general blast plan, and this provision as directed by the Engineer. Use explosives in accordance with all applicable government regulations, professional society standards and manufacturer guidelines and recommendations.

Remove all overburden material along the top of the excavation for a minimum of 30 ft (9.1 m) beyond the blast holes or the end of the cut unless otherwise approved. Inspect the free face to ensure there is adequate burden.

Drill blast holes within 3” (75 mm) of plan location and control drilling to maintain the final cut slope angle. Accurately determine the angle at which the drill steel enters the rock. Cover all blast holes after drilling to prevent unwanted backfill and identify and mark each hole with hole number and depth. Blast holes are required to be free of obstructions the entire depth. Load holes without dislodging material or caving in the blast hole wall. Use standard size nos. 67 and

78M in accordance with Section 1005 of the *Standard Specifications* for stemming. Stem blast holes with diameters of 5" (250 mm) or greater with no. 67 coarse aggregate and blast holes with diameters less than 5" (250 mm) with no. 78M coarse aggregate. Do not stem blast holes with drill cuttings. Matting is required when blasting in close proximity to buildings, residences, utilities, traffic and populated areas. Soil cover may be used in lieu of matting if allowed by the Engineer.

Notify all occupants of residences, businesses and structures in the surrounding area and the Engineer at least 24 hours before blasting. Check for misfires immediately after each blast before signaling all clear. Remove any loose, hanging or potentially dangerous conditions by hand or machine scaling methods. Resume drilling only after scaling is complete.

When the height of a cut requires multiple lifts or benches, offset the controlled blast holes for each subsequent lift the minimum distance necessary to allow for drill equipment clearances. Adjust the alignment of controlled blast holes to account for this offset as well as any drift that occurred in the preceding lift.

The Engineer may suspend blasting operations in accordance with Article 108-7 of the *Standard Specifications* when vibration, air-overpressure or flyrock limits are exceeded, unsatisfactory rock cut slopes are produced or other reasons.

Remove all loose material from final rock faces by scaling. The Contractor is responsible for the final rock face. If blasting damages the final rock face, stabilize the slope at no additional cost to the Department with a method proposed by the Contractor and accepted by the Department.

Secondary Blasting

Secondary blasting is used to reduce the size of naturally occurring boulders or those resulting from initial blasting. Secondary blasting methods include block holing or boulder busting. Block holing or boulder busting is the breaking of boulders by loading and firing small explosive charges in small diameter blast holes. Submit a combined general and site specific blast plan for secondary blasting. The Engineer may waive the pre-blast surveys, blast monitoring and post-blast reports at their discretion.

Mud capping, which is defined as placing an unconfined explosive charge in contact with a rock surface without the use of a blast hole and covering it with mud, is not allowed.

Blasting Adjacent to Highway Structures

Do not blast adjacent to highway structures until the concrete strength reaches 2400 psi (16.5 MPa). When blasting adjacent to highway structures, limit PPV to 4 in/sec (100 mm/sec) measured at a location on the structure nearest the blast. Perform blasting adjacent to highway structures in accordance with the submittal, blast design and construction requirements in this provision.

When blasting for foundation excavation, submit a combined general and site specific blast plan and the Engineer may waive the pre-blast surveys, blast monitoring and post-blast reports at their discretion.

Measurement and Payment

No direct payment for rock blasting or scaling will be made. The contract unit price for *Unclassified Excavation* in accordance with Article 225-7 of the *Standard Specifications* or the lump sum price for *Grading* in accordance with Article 226-3 of the *Standard Specifications* will be full compensation for all necessary rock blasting and scaling in accordance with the contract.

No direct payment for rock blasting will be made for any pipe, utility or foundation excavation. Rock blasting for these items will be considered incidental to the compensation for the required excavation at the various locations. Where no direct payment for excavation is made, the cost for all rock blasting will be considered incidental to the required work and no separate payment for blasting will be made.

No additional payment will be made or extension of contract time allowed when the Engineer suspends blasting operations and requires test blasts, additional monitoring or submittals in accordance with this provision.



TOE BENCHING EXCAVATION

1.0 DESCRIPTION

Excavate material necessary for the formation of benches in the existing ground beneath proposed embankments in order to increase the bond between the existing ground and the proposed embankment.

2.0 CONSTRUCTION METHODS

When embankments are to be placed and compacted on hillsides, or when new embankments are to be compacted against existing embankment, or when embankment is built in part widths, or at other locations designated by the Engineer, excavate benches in the existing ground in accordance with the detail shown on the plans and as directed by the Engineer.

Use where practical all material removed in the excavation in the formation of embankments. No excavation shall be wasted except as permitted by the Engineer. Disposed of waste material in a manner, which will not cause damage to adjacent property, nor mar the appearance of the completed roadway.

3.0 METHOD OF MEASUREMENT

The quantity of excavation to be paid for will be the actual number of cubic yards of materials, measured in their original position and computed by the average end area method, which have been acceptably excavated in accordance with the plans and specifications or as directed by the Engineer. Original cross-sections for the determination of excavation quantities will be taken before any grading begins. Final cross-sections will be the sections required by the plans or directed by the Engineer.

The upper bound of the benching excavation is the point at which the 5' by 5' typical benches as shown on the plans intersect the existing ground line.

No measurement will be made of any materials excavated outside of authorized excavation limits, or of any materials excavated before stakes have been set.

4.0 BASIS OF PAYMENT

The quantity of excavation, measured as provided for above, will be paid for at the contract unit price per cubic yard for "Toe Benching Excavation". The above prices and payments will be full compensation for all work covered by this section, including but not limited to

excavation, blasting, and hauling; disposal of materials; removal and disposal of stumps and the formation and compaction of embankments.

Payment will be made under:

Toe Benching Excavation.....Cubic Yard

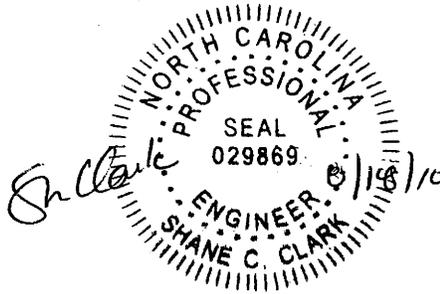


SOIL PLATING OF ROCK EMBANKMENTS

Plate all embankments constructed of Class II Riprap or Class VII Select material with soil as shown on the details in the plans and as directed by the Engineer.

The soil material shall be earth material derived from the project. The soil plating shall contain no rocks greater than 2 inches in diameter.

No additional compensation will be made for any requirements for furnishing and placing soil material as the cost of such work shall be included in the contract unit price for "Lump Sum Grading".



SOIL PLATED ROCK EMBANKMENT CONSTRUCTION

1.0 GENERAL

Construct rock embankments using Class II Riprap or Class VII Select Material in accordance with Section 235 of the Standard Specifications, the detail shown on the plans and the following provisions:

Drain rock embankments with weeps as indicated on the plans and as directed by the Engineer.

2.0 MATERIALS

Use earth material and Class II Riprap or Class VII stone derived from the project.

Use blasted rock and aggregate base course material to construct the rock embankments using Class II Riprap or Class VII select material as detailed in the plans and located at the following stations:

From Station	To Station	Side	Slope	
134+50	138+00	RT	1.5:1	FILL
229+00	239+50	RT	1.5:1	FILL

The rock shall meet the following requirements:

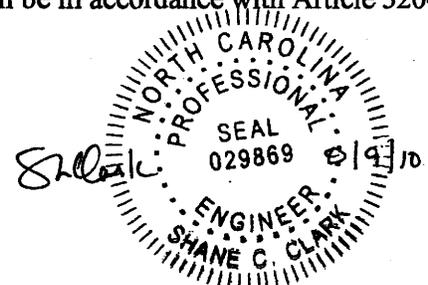
- a. Class II Riprap or Select Class VII in accordance with the Standard Specifications.
- b. No rippable rock will be permitted in the embankments.
- c. Density requirements will not apply to roadway embankment at the above locations, but the formation of roadway embankments shall be as outlined above.

The aggregate base course shall meet the requirements of Section 1016-3, Class IV; or material meeting gradation requirements of Table 1010-1, Column C.

3.0 COMPENSATION

No additional compensation will be made for any requirements for furnishing and placing Class II Riprap or Class VII Select Material or earth materials as the cost of such work shall be included in the contract unit price per cubic yard for "Lump Sum Grading".

Measurement and payment for Aggregate Base Course will be in accordance with Article 520-11 of the Standard Specifications.



TEMPORARY SOIL NAIL WALLS:

(SPECIAL)

Description

A soil nail is defined as a steel bar grouted in a drilled hole inclined at an angle below horizontal. A temporary soil nail wall consists of soil nails spaced at a regular pattern and connected to a reinforced shotcrete face supporting the excavation. At the Contractor's option, use temporary soil nail walls in lieu of temporary shoring for full cut sections. Design and construct temporary soil nail walls based on actual elevations and dimensions in accordance with the contract and accepted submittals. For this provision, "soil nail wall" refers to a temporary soil nail wall and "Soil Nail Wall Contractor" refers to the contractor installing soil nails and applying shotcrete. Use a Soil Nail Wall Contractor prequalified by the NCDOT Contractual Services Unit for anchored retaining walls work (work code 3020).

Materials

Provide Type 7 Contractor's Certifications in accordance with Article 106-3 of the *Standard Specifications* for soil nail materials and geocomposite drain strips. Store steel materials on blocking a minimum of 12" (300 mm) above the ground and protect it at all times from damage; and when placing in the work make sure it is free from dirt, dust, loose mill scale, loose rust, paint, oil or other foreign materials. Load, transport, unload and store soil nail wall materials such that they are kept clean and free of damage. Damaged or bent materials will be rejected.

(A) Soil Nails

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

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

Use grout in accordance with the contract.

Nail head assemblies consist of steel bearing plates, washers and nuts. Provide bearing plates meeting the requirements of ASTM A36 and washers and hex nuts in accordance with the bar manufacturer's recommendations.

(B) Geocomposite Drain Strips

Provide minimum average roll values (MARV) as defined by ASTM D4439 for core properties of drain strips. For testing drain strips, a lot is defined as a single day's production. Identify, store and handle drain strips in accordance with ASTM D4873.

Drain strips with defects, flaws, deterioration or damage will be rejected. Do not leave drain strips uncovered for more than 7 days.

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

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

* per ft (m) of width tested

(C) Shotcrete

Use shotcrete in accordance with the contract.

(D) Reinforcing Steel

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

Design

Before beginning design, survey Contractor designed shoring locations to determine existing elevations and actual design heights. Design soil nail walls in accordance with the plans and the allowable stress design method in the *FHWA Geotechnical Engineering Circular No. 7 "Soil Nail Walls"* (Publication No. FHWA-IF-03-017) unless otherwise required.

Provide portable concrete barriers in accordance with the contract for barriers for temporary mechanically stabilized earth (MSE) walls. For pavements above and behind soil nail walls, maintain a minimum clearance of 36" (900 mm) between the wall face and edge of pavement. For slopes above and behind soil nail walls, maintain a minimum clearance of 12" (300 mm) between the wall face and toe of slope.

Design soil nail walls for a 3-year design service life and a traffic surcharge equal to 240 psf (11.5 kPa). This surcharge is not applicable for construction traffic. If a construction surcharge will be present within a horizontal distance equal to the height of the wall, design the soil nail wall for the required construction surcharge.

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

(A) Vertical and horizontal spacing of 3 ft (1 m)

- (B) Inclination of 10 degrees below horizontal
- (C) Diameter of 4" (100 mm)

Geocomposite drain strips are required at minimum 10 ft (3 m) centers between the shotcrete and excavation face. Use a minimum shotcrete thickness of 4" (100 mm) and reinforce shotcrete with #4 (#13) whaler bars around each nail head. Two reinforcing bars (one on each side of the nail head) in both the vertical and horizontal directions for a total of 4 whaler bars per soil nail are required. Do not embed shotcrete facing below bottom of excavation or the grade in front of soil nail walls.

Submit soil nail wall designs including unit grout/ground bond strengths for review and acceptance in accordance with Article 105-2 of the *Standard Specifications*. Submit working drawings showing plan views, wall profiles with soil nail locations and typical sections with soil nail, drainage, shotcrete and reinforcing details. If necessary, include details on working drawings for obstructions interfering with soil nails or extending through walls. Also, submit a sequence and step-by-step description of soil nail wall construction including details of excavations, drilling and grouting methods, soil nail installation and testing and shotcreting. Submit design calculations for each soil nail wall section with different surcharge loads, wall geometry or material parameters. A minimum of one analysis is required for each wall section with different soil nail lengths. Submit 3 hard copies of design calculations and 10 hard copies of drawings and an electronic copy (PDF on CD or DVD) of both the calculations and drawings. Have soil nail walls designed, detailed and sealed by a Professional Engineer registered in North Carolina.

Construction Methods

When using an anchored NCDOT portable concrete barrier (PCB), anchor the barrier in accordance with Roadway Standard Drawing 1170.01 and Section 1170 of the *Standard Specifications*. Control drainage during construction in the vicinity of soil nail walls. Direct run off away from soil nail walls and areas above and behind walls.

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

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

Do not excavate behind soil nail walls. If overexcavation occurs, repair walls at no additional cost to the Department with a method proposed by the Contractor and accepted by the Engineer.

(A) Excavation

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

Install geocomposite drain strips as shown in the accepted submittals. Before shotcreting, place and secure drain strips with the geotextile side against the excavation face. Ensure that drain strips continuously contact the excavation face and allow for full flow the entire height of the wall. Discontinuous drain strips are not allowed. If splices are needed, overlap drain strips a minimum of 12" (300 mm) such that flow is not impeded.

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

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

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

Cut off excess drain strips and expose strip ends below shotcrete facing when excavation and shotcreting is complete.

(B) Soil Nail Installation

Drill and grout soil nails the same day and do not leave drill holes open overnight. Control drilling and grouting to prevent excessive ground movements, damaging structures and pavements and fracturing rock and soil formations. If ground heave or subsidence occurs, suspend soil nail wall construction and take action to minimize movement. If structures or pavements are damaged, suspend wall construction and repair

structures and pavements at no additional cost to the Department with a method proposed by the Contractor and accepted by the Engineer.

(1) Drilling

Use drilling rigs capable of drilling through whatever materials are encountered to the dimensions and orientations required for the soil nail wall design. Drill straight and clean holes at locations shown in the accepted submittals. Stabilize drill holes with temporary casings if unstable, caving or sloughing material is anticipated or encountered. Do not use drilling fluids to stabilize drill holes or remove cuttings.

(2) Soil Nail Bars

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

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

(3) Grouting

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

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

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

(4) Nail Heads

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

(C) Shotcreting

Perform shotcreting in accordance with the contract and accepted submittals. Use nozzlemen who made satisfactory preconstruction test panels.

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

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

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

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

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

(D) Soil Nail Testing

For this provision, “proof tests” are performed on test nails incorporated into the wall, i.e., production soil nails assuming test nails are acceptable in accordance with this provision. “Proof test nails” refer to soil nails on which proof tests are performed.

In general, proof tests on 5 percent of production soil nails with a minimum of 1 test per nail row is required. More or less soil nail testing may be required depending on the subsurface conditions encountered. The Engineer will decide the actual number and locations of proof tests.

Do not test soil nails until grout and shotcrete achieve the required 3 day compressive strength.

(1) Testing Equipment

Use testing equipment that includes the following.

- (a) 2 dial gauges with rigid supports
- (b) Hydraulic jack and pressure gauge
- (c) Jacking block or reaction frame

Use dial gauges capable of measuring to 0.001" (0.025 mm) and accommodating the maximum anticipated movement. Provide pressure gauges graduated in 100 psi (690 kPa) increments or less.

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

(2) Proof Tests

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

Soil nail bars for production soil nails may be overstressed under higher test nail loads. Use larger or higher grade steel bars to allow for higher loads instead of shortening bond lengths to less than the minimum.

Use the following equation to determine maximum bond lengths, L_B (ft or m).

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

where,

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

A_t = bar area (in² or m²),

f_y = bar yield stress (ksi or kPa) and

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

Use the following equation to determine design test loads, DTL (kips or kN).

$$DTL = L_B \times Q_{ALL}$$

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

Load	Hold Time
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	10 or 60 minutes (creep test)
AL*	1 minute

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

Reset dial gauges to zero after applying alignment load. Record test nail movement at each load increment and monitor test nails for creep at the 1.50 DTL load increment. Measure and record test nail movement at 1, 2, 3, 5, 6 and 10 minutes. When the test nail movement between 1 minute and 10 minutes exceeds 0.04" (1 mm), maintain the maximum test load for an additional 50 minutes and record movements at 20, 30, 50 and 60 minutes. Repump jack as needed to maintain the intended load during hold times.

(3) Test Nail Acceptance

Test nail acceptance is based on the following criteria.

- (a) Total creep movement is less than 0.04" (1 mm) between the 1 and 10 minute readings or less than 0.08" (2 mm) between the 6 and 60 minute readings and creep rate is linear or decreasing throughout the creep test load hold time.
- (b) Total test nail movement at maximum test load exceeds 80 percent of the theoretical elastic elongation of the test nail unbonded length.
- (c) Pullout failure does not occur at or before the 1.5 DTL load increment. Pullout failure is defined as the inability to increase the load while test nail movement continues. Record the pullout failure load as part of the test data.

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

(4) Test Nail Results

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

If the Engineer determines a test nail is unacceptable, either perform additional proof tests on adjacent production soil nails or revise the soil nail wall design for the production soil nails represented by the unacceptable proof test nail as determined by the Engineer. Submit a revised soil nail wall design for review and acceptance and provide an acceptable proof test nail with the revised design and/or installation methods at no additional cost to the Department. If required, remove representative production soil nails and/or provide new production soil nails with the revised design and/or installation methods at no additional cost to the Department.

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

Measurement and Payment

If the Contractor elects to use temporary soil nail walls in lieu of temporary shoring, the soil nail walls will be paid for at the contract unit price for *Temporary Shoring*. Temporary soil nail walls will be measured as the exposed face area with the wall height equal to the difference between the top and bottom of wall elevation. The top of wall elevation is defined as the top of shotcrete facing. The bottom of wall elevation is defined as where the grade intersects the front face of the soil nail wall. No payment will be made for portions of temporary soil nail walls below bottom of wall elevations or any pavement thickness above soil nail walls.

The contract unit price for *Temporary Shoring* will be full compensation for design, submittals, furnishing labor, tools, equipment and soil nail wall materials, excavating, installing soil nails and geocomposite drain strips, grouting, testing nails, shotcreting including test panels and providing reinforcement and any incidentals necessary to design and construct soil nail walls in accordance with this provision.



SOIL NAIL SLOPE STABILIZATION

(SPECIAL)

R-2710

1.0 GENERAL**A. Description**

A soil nail is defined as a steel bar grouted in a drilled hole inclined at an angle below horizontal. Soil nail slope stabilization consists of soil nails spaced at a regular pattern and connected to a flexible, steel wire mesh facing. Construct soil nail slope stabilization based on actual elevations and dimensions in accordance with this provision, the accepted submittals and the plans. For this provision, "Soil Nail Slope Stabilization Contractor" refers to the contractor installing the soil nails and applying the facing. **This project will have a combination of soil, weathered rock and competent rock in the subsurface. The contractor should be prepared to drill and install in these materials.**

2.0 SUBMITTALS

Two submittals are required. These submittals include (1) Soil Nail Slope Stabilization Contractor personnel and experience and (2) soil nail slope stabilization installation and testing plan. Provide 11 hard copies of working drawings and 4 hard copies of the remaining submittals. Also, submit an electronic copy (pdf or jpeg format on CD or DVD) of each submittal. Allow 10 calendar days for the review of the Soil Nail Slope Stabilization Contractor personnel and experience submittal. After the personnel and experience submittal is accepted, submit the remaining submittals at least 30 calendar days before starting soil nail slope stabilization construction. Do not begin soil nail slope stabilization construction including sacrificial soil nails for verification tests until the installation and testing plan is accepted.

A. Soil Nail Slope Stabilization Contractor Personnel and Experience Submittal

Use a Soil nail slope stabilization Contractor prequalified by the Construction Unit of the Department for anchored retaining walls work (work code 3020). Submit documentation that the Soil Nail Slope Stabilization Contractor has successfully completed at least 5 soil nail retaining wall projects and 500 soil nails within the last 3 years with an exposed face area for all 5 walls of at least 10,000 ft². Documentation should include the General Contractor and Owner's name and current contact information with descriptions of each past project.

Provide the names of the Superintendent and Project Manager that will be assigned to this project. Submit documentation for these personnel verifying employment with the Soil Nail Slope Stabilization Contractor. Submit documentation that the Superintendent and Project Manager each have a minimum of 5 years experience in soil nail construction with past projects of scope and complexity similar to that anticipated for this project. Documentation should include resumes, references, certifications, project lists, experience descriptions and details, etc. Perform work with the personnel

submitted and accepted. If personnel changes are required during construction, suspend soil nail slope stabilization construction until replacement personnel are submitted and accepted.

B. Soil Nail Slope Stabilization Installation and Testing Plan Submittal

Submit detailed project specific information including the following.

1. Excavation methods and equipment.
2. List and sizes of proposed drilling rigs and tools, tremies and grouting equipment.
3. Sequence and step-by-step description of soil nail slope stabilization construction including details of drilling and grouting methods, soil nail installation and facing construction.
4. Examples of construction and test nail records to be provided in accordance with Sections 6.0 and 7.0, Item F, respectively.
5. Grout mix design including laboratory test results in accordance with the Grout for Structures Special Provision and acceptable ranges for grout flow and density.
6. Soil nail testing details, procedures and plan sealed by a Professional Engineer registered in North Carolina with calibration certificates within one year of submittal date in accordance with Section 7.0.
7. Other information shown on the plans or requested by the Engineer.

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

3.0 MATERIALS

Provide Type 3 Manufacturer's Certifications in accordance with Article 106-3 of the *Standard Specifications* for soil nail materials.

A. Soil Nails

Store steel materials on blocking a minimum of 12" (300 mm) above the ground and protect it at all times from damage; and when placing in the work make sure it is free from dirt, dust, loose mill scale, loose rust, paint, oil or other foreign materials. Do not crack, fracture or otherwise damage grout inside sheathing of shop grouted encapsulated soil nails.

Use galvanized deformed steel bars meeting the requirements of AASHTO M31, Grade 75 (520) or M275. Splice bars in accordance with Article 1070-10 of the *Standard Specifications*. Minimum bar size allowed will be #6.

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

Use grout in accordance with the contract.

B. Wire Mesh, Connectors and Anchor Plates

The mesh shall be woven construction and shall be diamond shaped. The mesh shall be made with 0.118 inches (3-millimeter) diameter wire and the ends of each wire formed into a loop and twisted. The loops of the wire mesh shall be fastened together to prevent unraveling of the mesh. The wire shall be galvanized high strength alloy steel wire with a minimum tensile strength of 256,000 pounds per square inch (of 1,770 kilonewtons per square meter). The mesh shall have a minimal longitudinal tensile strength of 10,200 pounds per foot (150 kilonewtons per meter) for the 0.118 inch (3-millimeter mesh) and 17,130 pounds per foot (250 kilonewtons per meter) for the 0.157 inch (4-millimeter) mesh.

The wire shall be hot dipped galvanized with Zinc/Aluminum and the minimum weight of the coating shall be 0.49 ounces per square foot (150 grams per square meter). The coating shall be 95% Zinc and 5% Aluminum.

The mesh shall be 3 dimensional. The size of the mesh shall be 83 millimeters (3.27 inches) by 143 millimeters (5.63 inches) (+ 2%) and the depth shall be 15 millimeters (0.59 inches) (+ 1 mm). The mesh shall have 12 meshes per meter in the transverse direction and 7 meshes per meter in the longitudinal direction. The mesh shall be supplied in 3.5 meter (11.5 feet) wide by 30-meter (98.4 feet) long rolls.

Use manufacturer's recommended mesh anchoring plates for attaching the slope to the slope. Use manufacturer's recommended method for attaching overlaps and performing field splices in the mesh material.

4.0 SOIL NAIL SLOPE STABILIZATION PRECONSTRUCTION MEETING

Before starting soil nail slope stabilization construction, conduct a preconstruction meeting to discuss the construction and inspection of the soil nail slope stabilizations. Schedule this meeting after all soil nail slope stabilization submittals have been accepted. The Resident or Bridge Maintenance Engineer, Bridge Construction Engineer, Geotechnical Operations Engineer, General Contractor and the Soil Nail Slope Stabilization Contractor Superintendent, and Project Manager will attend this preconstruction meeting.

5.0 CONSTRUCTION METHODS

Perform all necessary clearing and grubbing in accordance with Section 200 of the *Standard Specifications*. Perform any blasting in accordance with the contract special provisions. Do not excavate beyond the face of the soil nail slope stabilization.

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

A. Excavation

Construct the soil nail slope stabilization from the top down. Excavate in staged horizontal lifts with heights not to exceed the vertical soil nail spacing. The excavated surface must be to the grades of the project drawings for the slope. Do not excavate the slope more than 3 feet (1 m) below the level of the row of nails to be installed in that lift. Do not excavate a lift until nail installation and nail testing for the preceding lift are complete and acceptable to the Engineer. After a lift is excavated, clean the cut surface of all loose materials, mud, and other foreign material. Prior to advancing the excavation, allow nail grout on the preceding lift to achieve the required 3 day compressive strength.

If the excavation face becomes unstable at any time, suspend soil nail slope stabilization construction and temporarily stabilize the face by immediately placing an earth berm against the unstable face. Soil nail slope stabilization construction may not proceed until the conditions have been reviewed by the Engineer. A revised soil nail slope stabilization installation and testing plan submittal may be required after the slope conditions have been reviewed.

Take all necessary measures to ensure that installed nails are not damaged during excavation. Repair or replace to the satisfaction of the Engineer and at no cost to the Department nails that are damaged or disturbed during excavation.

B. Installation of Wire Mesh and Bearing Plates

Prior to installing wire mesh, excavate depression around each nail location as shown in plans. Install wire mesh in accordance with the drawings and manufacturer's specifications, including any required overlapping.

Following soil installation, connect the bearing plates to the nails as shown on the plans and as directed by the Engineer. Replace bearing plates, nuts or washers that are damaged or defective as determined by the Engineer at no additional cost to the Department. Once the bearing plates and nuts have been attached to the nails, tighten each nut until they have reached a torque reading of 265 ft-lbs.

C. Soil Nail Installation

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

supplemental soil nails, as directed by the Engineer, to a depth of 10 feet beyond the slope face through the wire mesh to improve contact with the slope face.

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

1. Drilling

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

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

Using manufacturer approved methods, increase the opening in the wire mesh to allow installation of the soil nail through the mesh.

2. Soil Nail Bars

Use centralizers to center steel bars in drill holes. Securely attach centralizers at maximum 8 ft (2.4 m) intervals along bars. Attach upper and lowermost centralizers 24" (450 mm) from the top and bottom of the bars.

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

3. Grouting

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

Place grout with a tremie in accordance with the contract and accepted submittals. Inject grout at the lowest point of drill holes through a tremie pipe, e.g., grout tube, casing, hollow-stem auger or drill rod, in one continuous operation. Fill drill holes

progressively from the bottom to top and withdraw tremie at a slow even rate as the hole is filled to prevent voids in the grout. Extend tremie pipe into grout a minimum of 5 ft at all times except when grout is initially placed in a drill hole.

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

Bar threads should be kept clean to allow tightening of the anchor plate and nut.

6.0 CONSTRUCTION RECORDS

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

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

After completing all lifts for a soil nail slope stabilization or a stage of a soil nail slope stabilization, submit electronic copies (pdf or jpg format on CD or DVD) of all corresponding construction records.

7.0 SOIL NAIL TESTING

For this provision, “verification tests” are performed on test nails not incorporated into the work, i.e., sacrificial soil nails “Verification test nails” refer to soil nails on which verification tests are performed and “proof test nails” refer to soil nails on which proof tests are performed.

One verification test is required at each soil nail slope stabilization location, or as directed by the Engineer. The Engineer will select the test location in the field. Proof tests on 5 percent of production soil nails with a minimum of 1 test per nail row are required. More or less soil nail testing may be required depending on the subsurface conditions encountered. The Engineer will decide the actual number and specific locations of each verification and proof test required.

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

A. Testing Equipment

Use testing equipment that includes the following.

- 2 dial gauges
- dial gauges rigid supports
- hydraulic jack and pressure gauge
- electronic load cell
- jacking block or reaction frame

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

Align testing equipment to ensure uniform loading. Use a jacking block or reaction frame that does not damage the slope or contact the slope face within 3 ft (1 m) of test nails. Align dial gauges within 5 degrees of the test nail axis. Place dial gauges opposite each other on either side of the test nail. Set up test equipment and measuring devices such that resetting or repositioning the components before completing testing is not required. A load cell is not required for proof tests if the same jack and pressure gauge are used for verification tests.

B. Test Nails

Test nails have both bonded and unbonded lengths. Grout only the bonded length before testing. Minimum bonded and unbonded lengths of 10 ft and 5 ft, respectively, are required.

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

C. Verification Tests

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

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

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

Where,

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

A_t = bar area (in² or m²),

f_y = bar yield stress (ksi or kPa) and

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

Use the following equation to determine design verification test load, DTL (kips or kN).

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

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

Load	Hold Time
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	60 minutes (creep test)
1.75 DTL	10 minutes
2.00 DTL	10 minutes
2.50 DTL	10 minutes
3.00 DTL	10 minutes
AL*	1 minute

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

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

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

D. Proof Tests

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

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

Where variables are as defined in Item C of this section.

Use the following equation to determine design proof test load, DTL (kips or kN).

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

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

Load	Hold Time
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	10 or 60 minutes (creep test)
AL*	1 minute

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

Reset dial gauges to zero after applying alignment load. Record test nail movement at each load increment and monitor test nails for creep at the 1.50 DTL load increment. Measure and record test nail movement at 1, 2, 3, 5, 6 and 10 minutes. When the test nail movement between 1 minute and 10 minutes exceeds 0.04” (1 mm), maintain the maximum test load for an additional 50 minutes and record movements at 20, 30, 50 and 60 minutes. Repump jack as needed to maintain the intended load during hold times.

E. Test Nail Acceptance

Test nail acceptance is based on the following criteria.

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

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

F. Test Nail Results

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

If the Engineer determines a verification test nail is unacceptable, the Engineer may revise the soil nail slope stabilization design and/or installation methods. The Engineer will have up to 10 working days to revise the soil nail slope stabilization design and/or installation and testing plan at no additional cost to the Department.

If the Engineer determines a proof test nail is unacceptable as a result of the contractor's activities, then either additional proof tests on adjacent production soil nails or a revision to the soil nail slope stabilization design and/or installation methods for the production soil nails represented by the unacceptable proof test nail may be required at no additional cost to the Department. If required, remove representative production soil nails and provide new production soil nails with the revised design and/or installation methods at no additional cost to the Department.

After completing all soil nail testing, submit electronic copies (pdf or jpg format on CD or DVD) of all corresponding testing records.

8.0 MEASUREMENT AND PAYMENT

Soil Nail Slope Stabilization will be measured and paid for at the contract unit price per square yard of the slope stabilization system measured along the surface of the slope that has been incorporated into the completed and accepted work.

Include in the unit bid price for *Soil Nail Slope Stabilization* all costs for submittals, furnishing labor, tools, equipment and materials, excavating lifts, installing soil nails, grouting, wire mesh and any incidentals necessary to design and construct soil nail slope stabilization in accordance with this provision.

Supplemental Soil Nails will be measured and paid for at the contract unit price per each to construct additional soil nails into the completed and accepted work. Include in the unit bid price all costs for furnishing labor, tools, equipment and materials, installing soil nails, grouting, and any incidentals necessary to construct supplemental soil nails in accordance with this provision. No payment will be made for supplemental soil nails that are required due to Contractor negligence during excavation.

Soil Nail Verification Tests and *Soil Nail Proof Tests* will be measured and paid for per each, depending on the type of test. Include in these unit bid prices all costs for soil nail testing in accordance with Section 7.0 of this provision. The Department will only pay for the initial verification or proof test on an initial test nail required by the Engineer; no payment will be made for subsequent tests performed on the same test nail or replacement test nails.

Pay Item

Soil Nail Slope Stabilization
Supplemental Soil Nails
Soil Nail Verification Tests
Soil Nail Proof Tests

Pay Unit

Square Yard
Each
Each
Each



GROUT FOR STRUCTURES

(SPECIAL)

R-2710

1.0 DESCRIPTION

This special provision addresses grout for use in structures, including continuous flight auger (CFA) piles, micropiles, soil nail and anchored retaining walls and backfilling crosshole sonic logging (CSL) tubes or grout pockets, shear keys, dowel holes and recesses for cored slabs and box beams. This provision does not apply to grout placed in post-tensioning ducts for bridge beams, girders or decks. Provide grout composed of portland cement, water and at the Contractor's option, fine aggregate and/or pozzolan. If necessary, use set controlling admixtures. Proportion, mix and place grout in accordance with the plans, the applicable section of the *Standard Specifications* or special provision for the application and this provision.

2.0 MATERIALS

Refer to Division 10 of the *Standard Specifications*:

Item	Article
Portland Cement	1024-1
Water	1024-4
Fine Aggregate	1014-1
Fly Ash	1024-5
Ground Granulated Blast Furnace Slag	1024-6
Admixtures	1024-3

At the Contractor's option, use an approved packaged grout in lieu of the materials above with the exception of the water. Contact the Materials and Tests (M&T) Unit for a list of approved packaged grouts. Consult the manufacturer to determine if the packaged grout selected is suitable for the application and meets the compressive strength and shrinkage requirements.

3.0 REQUIREMENTS

Unless required elsewhere in the Contract, provide non-metallic grout with minimum compressive strengths as follows:

Property	Requirement
Compressive Strength @ 3 days	2500 psi (17.2 MPa)
Compressive Strength @ 28 days	4500 psi (31.0 MPa)

For applications other than micropiles, soil nails and ground anchors, use non-shrink grout with shrinkage of less than 0.15%.

When using approved packaged grout, a grout mix design submittal is not required. Submit grout mix designs in terms of saturated surface dry weights on M&T Form 312U in accordance with the applicable section of the *Standard Specifications* or special provision for the structure. Use an approved testing laboratory to determine the grout mix proportions. Adjust proportions to compensate for surface moisture contained in the aggregates at the time of mixing. Changes in the saturated surface dry mix proportions will not be permitted unless a revised grout mix design submittal is accepted.

For each grout mix design, provide laboratory test results for compressive strength, density, flow and if applicable, aggregate gradation and shrinkage. Submit compressive strength for at least 3 cube and 2 cylinder specimens at the age of 3, 7, 14 and 28 days for a total of at least 20 specimens tested. Perform laboratory tests in accordance with the following:

Property	Test Method
Compressive Strength	AASHTO T106 and T22
Density	AASHTO T133
Flow for Sand Cement Grout	ASTM C939 (as modified below)
Flow for Neat Cement Grout (no fine aggregate)	Marsh Funnel and Cup API RP 13B-1, Section 2.2
Aggregate Gradation for Sand Cement Grout	AASHTO T27
Shrinkage for Non-shrink Grout	ASTM C1090

When testing grout for flow in accordance with ASTM C939, modify the flow cone outlet diameter from ½ to ¾ inch (13 to 19 mm).

When grout mix designs are submitted, the Engineer will review the mix designs and notify the Contractor as to their acceptability. Do not use grout mix designs until written acceptance has been received. Acceptance of grout mix designs or use of approved packaged grouts does not relieve the Contractor of responsibility to furnish a product that meets the Contract requirements.

Upon written request from the Contractor, a grout mix design accepted and used satisfactorily on a Department project may be accepted for use on other projects.

4.0 SAMPLING AND PLACEMENT

The Engineer will determine the locations to sample grout and the number and type of samples collected for field and laboratory testing. Use API RP 13B-1 for field testing grout flow and density of neat cement grout. The compressive strength of the grout will be considered the average compressive strength test results of 3 cube or 2 cylinder specimens at 28 days.

Do not place grout if the grout temperature is less than 50°F (10°C) or more than 90°F (32°C) or if the air temperature measured at the location of the grouting operation in the shade away from artificial heat is below 40°F (4°C).

Provide grout at a rate that permits proper handling, placing and finishing in accordance with the manufacturer's recommendations unless directed otherwise by the Engineer. Use

grout free of any lumps and undispersed cement. Agitate grout continuously before placement.

Control grout delivery so the interval between placing batches in the same component does not exceed 20 minutes. Place grout before the time between adding the mixing water and placing the grout exceeds that in the table below.

ELAPSED TIME FOR PLACING GROUT (with continuous agitation)		
Air or Grout Temperature Whichever is Higher	Maximum Elapsed Time	
	No Set Retarding Admixture Used	Set Retarding Admixture Used
90°F (32°C) or above	30 min.	1 hr. 15 min.
80°F (27°C) through 89°F (31°C)	45 min.	1 hr. 30 min.
79°F (26°C) or below	60 min.	1 hr. 45 min.

5.0 MISCELLANEOUS

Comply with Articles 1000-9 through 1000-12 of the *Standard Specifications* to the extent applicable for grout in lieu of concrete.



SHORED MECHANICALLY STABILIZED EARTH RETAINING WALLS (R-2710)**1.0 GENERAL****A. Description**

A Shored Mechanically Stabilized Earth (SMSE) retaining wall is defined as a soil retaining system with steel or geogrid tensile reinforcements in the reinforced zone and vertical or nearly vertical precast concrete panels, combined with a soil nail wall system consisting of soil nails spaced at a regular pattern and connected to a reinforced shotcrete face supporting the excavation. When a composite MSE and Soil Nail Wall system is proposed on a project, the MSE component of the system should consider the long-term retaining benefits provided by the Soil Nail Wall. Contributions of the Soil Nail wall include a reduction in lateral loads on the MSE mass and significant contributions to global stability.

Design and construct SMSE retaining walls based on actual elevations and dimensions in accordance with the contract and accepted submittals. For this provision, "SMSE Wall" refers to the entire wall system, "MSE wall" refers to the mechanically stabilized earth wall part of the SMSE wall, "Soil Nail Wall" refers to the soil nail wall part of the SMSE wall.

Use a MSE Wall Installer prequalified by the NCDOT Contractual Services Unit for constructing the MSE wall (work code 3015). Use a Soil Nail Wall Contractor prequalified by the NCDOT Contractual Services Unit for designing and constructing the Soil Nail Wall (work code 3020).

B. MSE Wall System

Use a MSE wall system approved by the Department in accordance with any restrictions for the chosen system, the plans and the *NCDOT Policy for Mechanically Stabilized Earth Retaining Walls*. Value engineering proposals for other MSE wall systems will not be considered. Obtain the NCDOT MSE wall policy and the list of approved MSE wall systems from:

<http://www.ncdot.org/doh/preconstruct/highway/geotech/msewalls/>

Only fully approved MSE wall systems are allowed.

2.0 SMSE WALL DESIGN SUBMITTALS

Submit 11 hard copies of working drawings and 3 hard copies of design calculations and an electronic copy (PDF on CD or DVD) of each SMSE wall design submittal. Provide the submittal at least 30 calendar days before conducting the SMSE wall preconstruction meeting. Do not begin SMSE wall construction until the design submittal is accepted.

The Retaining Wall Plans show plan views, typical sections, details, notes and elevation or profile views (wall envelope) for each SMSE wall. Before beginning SMSE wall design,

survey existing ground elevations shown on the plans and submit a revised wall envelope for review and acceptance. Use the accepted revised wall envelope for design.

If existing or future obstructions such as foundations, guardrail posts, pavements, pipes, inlets or utilities will interfere with reinforcement, maintain a minimum clearance of 3" (75 mm) between the obstruction and reinforcement unless otherwise approved. Place reinforcement within 3" (75 mm) above the corresponding connection elevation.

(A) MSE Wall Design

Design MSE walls in accordance with any restrictions for the chosen MSE wall system, the plans and FHWA Publication *FHWA-CFL/TD-06-001* and other requirements stated below.

Design MSE walls with a minimum reinforcement length of 5 feet (1.5 meters) or 0.4 times the wall height, whichever is greater; except for the top two layers of reinforcement, which must have a minimum length of 5 feet (1.5 meters) and 0.6 times the wall height. Where the reinforcement length is less than 0.5 times the wall height, use a factor of safety against reinforcement pullout of 2.0. Use a maximum vertical reinforcement spacing of 2.5 feet (0.75 meters). Extend the reinforcement to the soil nail wall, where applicable, otherwise extend the select material 6" (150 mm) beyond the end of the reinforcement.

For geogrid reinforcement, use the reinforcement coefficients and geogrid reduction factors submitted to the Department for the approval of the chosen MSE wall system. For metallic reinforcement, for zinc use a corrosion loss rate of 0.6 mils/year (15 um/year) for the first two years and 0.16 mils/year (4 um/year) thereafter. For carbon steel, use a corrosion loss rate of 0.5 mils/year (12 um/year).

Use 6 inch (150 mm) thick cast-in-place unreinforced concrete leveling pads beneath panels that are continuous at steps and extend a minimum of 6" (150 mm) in front of and behind bottom row of panels. Unless required otherwise on the plans, embed top of leveling pads in accordance with *FHWA-CFL/TD-06-001* For slopes steeper than 3:2 (H:V), use an embedment of H/3. Extend a continuous drain along the base of the reinforced zone behind the select material. Provide drains meeting the requirements of an aggregate shoulder drain in accordance with Roadway Standard Drawing No. 816.02.

Use select material in the reinforced zone for MSE walls. Separation fabric is required between select material and overlying fill or aggregate with the exception of when concrete pavement is placed directly on the select material. Separation fabric may also be required between stone and backfill or natural ground as determined by the Engineer.

Unless shown otherwise on the plans, use reinforced concrete coping at top of walls with dimensions shown on the plans. Extend coping a minimum of 6" (150 mm) above where finished grade intersects the back of MSE walls unless required otherwise on the plans. Cast-in-place concrete coping is required when noted on plans. At the Contractor's option, connect cast-in-place concrete coping to panels with dowels or extend coping down the back of the MSE walls. Also, connect cast-in-place leveling concrete for precast concrete

coping to panels with dowels. When barriers are required above SMSE walls, use concrete barrier rails with moment slabs in accordance with the plans and design reinforcement for impact loads in accordance with the *AASHTO Standard Specifications for Highway Bridges* unless otherwise required.

Submit working drawings and design calculations for review and acceptance in accordance with Article 105-2 of the *Standard Specifications*. Submit working drawings showing plan views, wall profiles with maximum applied bearing pressures, typical sections with reinforcement connection details, select material type and separation fabric locations and details of leveling pads, facing elements, coping, bin walls, slip joints, etc. If necessary, include details on working drawings for concrete barrier rails with moment slabs, reinforcement connected to end bent caps and obstructions interfering with reinforcement or extending through walls. Submit design calculations for each wall section with different surcharge loads, geometry or material parameters. A minimum of one analysis is required for each wall section with different reinforcement lengths. When using a software program other than MSEW by ADAMA Engineering, Inc. for design, provide a hand calculation verifying the analysis of the section with the longest reinforcement length. Have SMSE walls designed, detailed and sealed by a Professional Engineer registered in North Carolina.

(B) Soil Nail Wall Design

Design soil nail walls for a 100-year design service life and a traffic surcharge equal to 240 psf (11.5 kPa). This surcharge is not applicable for construction traffic. If a construction surcharge will be present within a horizontal distance equal to the height of the wall, design the soil nail wall for the required construction surcharge.

At the judgement of the Engineer, the soil nail wall can be omitted where rock is encountered and is strong enough to support the excavation.

Batter the soil nail wall to 1:14 (H:V). For pavements above soil nail walls, maintain a minimum clearance of 36" (900 mm) between the smse wall face and edge of pavement. For slopes above soil nail walls, maintain a minimum clearance of 12" (300 mm) between the wall face and toe of slope.

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

- (1) Vertical and horizontal spacing of 3 ft (1 m)
- (2) Inclination of 10 degrees below horizontal
- (3) Diameter of 4" (100 mm)

Geocomposite drain strips are required at minimum 10 ft (3 m) centers between the shotcrete and excavation face. Use a minimum shotcrete thickness of 4" (100 mm) and reinforce shotcrete with #4 (#13) whaler bars around each nail head. Two reinforcing bars (one on each side of the nail head) in both the vertical and horizontal directions for a total of 4 whaler bars per soil nail are required. Do not embed shotcrete facing below bottom of excavation or the grade in front of soil nail walls.

Submit soil nail wall designs including unit grout/ground bond strengths for review and acceptance in accordance with Article 105-2 of the *Standard Specifications*. Submit working drawings showing plan views, wall profiles with soil nail locations and typical sections with soil nail, drainage, shotcrete and reinforcing details. If necessary, include details on working drawings for obstructions interfering with soil nails or extending through walls. Also, submit a sequence and step-by-step description of soil nail wall construction including details of excavations, drilling and grouting methods, soil nail installation and testing and shotcreting. Submit design calculations for each soil nail wall section with different surcharge loads, wall geometry or material parameters. A minimum of one analysis is required for each wall section with different soil nail lengths. Submit 3 hard copies of design calculations and 10 hard copies of drawings and an electronic copy (PDF on CD or DVD) of both the calculations and drawings. Have soil nail walls designed, detailed and sealed by a Professional Engineer registered in North Carolina.

3.0 MATERIALS

A. Certifications, Storage and Handling

Provide certifications in accordance with Article 106-3 of the *Standard Specifications*. Provide Type 7 Contractor's Certifications for soil nail materials and geocomposite drain strips. Provide Type 2 typical Certified Mill Test Reports for geogrid tensile strength. Provide Type 3 Manufacturer's Certifications for all other materials.

Load, transport, unload and store SMSE wall materials such that they are kept clean and free of damage. Damaged panels with excessive discoloration, chips or cracks as determined by the Engineer will be rejected. Store steel materials on blocking a minimum of 12" (300 mm) above the ground and protect it at all times from damage; and when placing in the work make sure it is free from dirt, dust, loose mill scale, loose rust, paint, oil or other foreign materials. Damaged or bent materials will be rejected.

Identify, store and handle geogrids and fabrics in accordance with ASTM D4873. Geogrids and fabrics with defects, flaws, deterioration or damage will be rejected. Do not leave geogrids and fabrics uncovered for more than 7 days

B. Facing Elements

Provide facing elements produced by a manufacturer approved or licensed by the MSE wall Vendor.

1. Precast Concrete Panels

Provide precast concrete panels meeting the requirements of Sections 1000 and 1077 of the *Standard Specifications* and reinforcing steel meeting the requirements of Section 1070 of the *Standard Specifications*. Accurately locate and secure reinforcement connection hardware and maintain a minimum 2" (50 mm) clearance to the reinforcing steel. Produce panels within 1/4 inch (6 mm) of the panel dimensions shown in the accepted submittals.

A minimum compressive strength of 4000 psi (27.6 MPa) at 28 days is required. For testing panels for compressive strength, 4 cylinders are required per 2000 ft² (186 m²) of panel face area or a single day's production, whichever is less.

Unless required otherwise on the plans, provide a final finish in accordance with Article 1077-11 of the *Standard Specifications*.

C. Reinforcement

Provide reinforcement supplied by the MSE wall Vendor or a manufacturer approved or licensed by the vendor.

1. Steel (Inextensible) Reinforcement

Use welded wire reinforcement mesh and mats meeting the requirements of AASHTO M55 or M221 and steel strips or straps meeting the requirements of ASTM A572 or A1011 with a grade as specified in the accepted submittals. Galvanize steel reinforcement in accordance with Section 1076 of the *Standard Specifications*.

2. Geogrid (Extensible) Reinforcement

Use geogrids approved by the Department for the chosen MSE wall system. Obtain the list of approved geogrids for each MSE wall system from the website shown elsewhere in this provision.

Test geogrids in accordance with ASTM D6637. Provide minimum average roll values (MARV) as defined by ASTM D4439 for tensile strength of geogrids. For testing geogrids, a lot is defined as a single day's production.

D. Select Material

Provide select material meeting the requirements of standard size nos. 57, 67 or 78M in accordance with Sections 1005 and 1014 of the *Standard Specifications*. Use select material free of deleterious materials with a maximum organic content of 1% tested in accordance with AASHTO T267.

E. Miscellaneous Components

Miscellaneous components may include attachment devices, connectors (e.g., pins, bars, plates, etc.), bearing pads, dowels, fasteners (e.g., bolts, nuts, etc.), filter fabric

and any other wall components not included above. Galvanize steel components in accordance with Section 1076 of the *Standard Specifications*. Provide miscellaneous components approved by the Department for the chosen MSE wall system. Obtain the list of approved miscellaneous components for each MSE wall system from the website shown elsewhere in this provision.

F. Coping, Leveling Concrete and Pads

Provide concrete coping and leveling pads meeting the requirements of Section 1000 of the *Standard Specifications* and reinforcing steel meeting the requirements of Section 1070 of the *Standard Specifications*. Provide precast coping meeting the requirements of Section 1077 of the *Standard Specifications* and leveling concrete for precast coping meeting the requirements of Section 1000 of the *Standard Specifications*.

Use Class A Concrete for coping, leveling concrete and pads in accordance with Article 1000-4 of the *Standard Specifications*. For testing precast coping for compressive strength, 4 cylinders are required per 40 yd³ (31 m³) of concrete or a single day's production, whichever is less.

G. Wall Drainage Systems

Wall drainage systems consist of drains and outlet components. Use shoulder drain materials meeting the requirements of Section 816 of the *Standard Specifications*.

H. Separation Fabrics

Use separation fabrics meeting the requirements of Type 2 Engineering Fabric in accordance with Section 1056 of the *Standard Specifications*.

I. Concrete Barrier Rails with Moment Slabs

Provide concrete barrier rails with moment slabs meeting the requirements of Section 1000 of the *Standard Specifications* and reinforcing steel meeting the requirements of Section 1070 of the *Standard Specifications*.

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

J. Joint Materials

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

K. Soil Nails

A soil nail is defined as a steel bar grouted in a drilled hole inclined at an angle below horizontal. A soil nail consists of a grouted steel bar with corrosion protection and a nail head assembly. Use epoxy coated or encapsulated deformed steel bars meeting the

requirements of AASHTO M275 or M31, Grade 60 or 75 (420 or 520). Splice bars in accordance with Article 1070-10 of the *Standard Specifications*.

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

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

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

Use grout in accordance with the contract.

Nail head assemblies consist of steel bearing plates, washers and nuts. Provide bearing plates meeting the requirements of ASTM A36 and washers and hex nuts in accordance with the bar manufacturer’s recommendations.

L. Composite Drain Strips

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

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

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

* per ft (m) of width tested

M. Shotcrete

Use shotcrete in accordance with the contract.

N. Concrete Reinforcing Steel

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

4.0 CORROSION MONITORING

Corrosion monitoring is required for SMSE walls with steel reinforcement. The Engineer will determine the number of monitoring locations and where to install the instrumentation. Contact the NCDOT Materials & Tests (M&T) Unit before beginning wall construction. M&T will provide the corrosion monitoring instrumentation kits and assistance with installation, if necessary.

5.0 SMSE WALL PRECONSTRUCTION MEETING

Before starting SMSE wall construction, conduct a preconstruction meeting to discuss the construction and inspection of the SMSE walls. Schedule this meeting after all SMSE wall submittals have been accepted. The Resident or Bridge Maintenance Engineer, Bridge Construction Engineer, Geotechnical Operations Engineer, Contractor and SMSE Wall Installer Superintendent will attend this preconstruction meeting.

6.0 SMSE WALL VENDOR SITE ASSISTANCE

Provide a representative employed by the MSE wall vendor to assist and guide the SMSE Wall Installer on-site for at least 8 hours when the first panels are set and the first reinforcement layer is placed unless otherwise approved. If problems are encountered during construction, the Engineer may require the vendor representative to return to the site for a time period determined by the Engineer at no additional cost to the Department.

7.0 CONSTRUCTION METHODS

Control drainage during construction in the vicinity of SMSE walls. Direct run off away from SMSE walls, select material and backfill. Contain and maintain select material and backfill and protect material from erosion.

Construct to the tolerances found in Table 4 of FHWA-CFL/TD-06-001.

Perform necessary clearing and grubbing in accordance with Section 200 of the *Standard Specifications*. Excavate as necessary for SMSE walls in accordance with the accepted submittals.

(A) MSE Wall Installation

Unless prohibited by a note on plans, install foundations located in the reinforced zone before placing select material or the first reinforcement layer. Notify the Engineer when foundation excavation is complete. Do not place leveling pad concrete, select material or reinforcement until obtaining approval of the excavation depth and foundation material.

Construct cast-in-place concrete leveling pads at elevations and with dimensions shown in the accepted submittals and in accordance with Section 420 of the *Standard Specifications*. Cure leveling pads a minimum of 24 hours before placing panels.

Erect and support panels with no negative batter (wall face leaning forward) such that the final position is as shown in the accepted submittals. Set panels with a joint width of 1/2 to 1 inch (13 to 25 mm).

Place reinforcement at the locations and elevations shown in the accepted submittals. Do not splice reinforcement. Contact the Engineer when unanticipated existing or future obstructions such as foundations, guardrail posts, pavements, pipes, inlets or utilities will interfere with reinforcement. To avoid obstructions, deflect, skew and modify reinforcement as shown in the accepted submittals.

Place select material in the reinforced zone in 8 to 10 inch (200 to 250 mm) thick lifts. Use only hand operated compaction equipment within 3 ft (1 m) of the wall face. At a distance greater than 3 ft (1 m), compact select material with at least 4 passes of an 8 – 10 ton (7.3 - 9.1 metric ton) vibratory roller. Smooth wheeled or rubber tired rollers are also acceptable for compacting select material. Do not use sheepsfoot, grid rollers or other types of compaction equipment with feet. Compact select material in a direction parallel to the wall face. Do not damage reinforcement when placing and compacting select material. End dumping directly on the reinforcement is not permitted. Do not operate heavy equipment on the reinforcement until it is covered with at least 10” (250 mm) of select material. Replace any damaged reinforcement to the satisfaction of the Engineer. Backfill for wall construction outside the reinforced zone in accordance with Article 410-8 of the *Standard Specifications*.

Install wall drainage systems as shown in the accepted submittals and in accordance with Section 816 of the *Standard Specifications*. Provide drains with positive drainage towards outlets.

Place and construct coping and leveling concrete as shown in the accepted submittals. Construct cast-in-place concrete coping, leveling concrete and moment slabs in accordance with Section 420 of the *Standard Specifications*. Do not remove forms until concrete achieves a minimum compressive strength of 2400 psi (16.5 MPa). Provide a Class 2 Surface Finish for cast-in-place concrete coping in accordance with Article 420-17 of the *Standard Specifications*. Construct concrete barrier rails with moment slabs in accordance with the plans and concrete barrier rails in accordance with Subarticle 460-3(C) of the *Standard Specifications*.

Construct cast-in-place concrete coping joints at a maximum spacing of 10 ft (3 m) to coincide with vertical joints between panels. Half-inch (13 mm) thick expansion joints in accordance with Article 420-10 of the *Standard Specifications* are required every third joint. Half-inch (13 mm) deep grooved contraction joints in accordance with Subarticle 825-10(B) of the *Standard Specifications* are required for the remaining joints. Stop coping reinforcement 2” (50 mm) from either side of expansion joints.

When separation fabric is required, overlap fabric a minimum of 18" (450 mm) with seams oriented parallel to the wall face. Seal joints above and behind SMSE walls between coping and ditches with joint sealer as shown on the plans.

When using an anchored NCDOT portable concrete barrier (PCB), anchor the barrier in accordance with Roadway Standard Drawing 1170.01 and Section 1170 of the *Standard Specifications*.

(B) Soil Nail Excavation

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

Do not excavate behind soil nail walls. If overexcavation occurs, repair walls at no additional cost to the Department with a method proposed by the Contractor and accepted by the Engineer.

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

Install geocomposite drain strips as shown in the accepted submittals. Before shotcreting, place and secure drain strips with the geotextile side against the excavation face. Ensure that drain strips continuously contact the excavation face and allow for full flow the entire height of the wall. Discontinuous drain strips are not allowed. If splices are needed, overlap drain strips a minimum of 12" (300 mm) such that flow is not impeded.

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

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

Do not excavate the next lift until the soil nail installations, shotcrete application, nail head assemblies and soil nail testing for the preceding lift are complete and the soil nails for the

preceding lift are accepted by the Engineer. Also, do not excavate the next lift until the grout and shotcrete for the preceding lift have cured at least 3 days and 1 day, respectively.

Cut off excess drain strips and expose strip ends below shotcrete facing when excavation and shotcreting is complete.

(C) Soil Nail Installation

Drill and grout soil nails the same day and do not leave drill holes open overnight. Control drilling and grouting to prevent excessive ground movements, damaging structures and pavements and fracturing rock and soil formations. If ground heave or subsidence occurs, suspend soil nail wall construction and take action to minimize movement. If structures or pavements are damaged, suspend wall construction and repair structures and pavements at no additional cost to the Department with a method proposed by the Contractor and accepted by the Engineer.

(1) Drilling

Use drilling rigs capable of drilling through whatever materials are encountered to the dimensions and orientations required for the soil nail wall design. Drill straight and clean holes at locations shown in the accepted submittals. Stabilize drill holes with temporary casings if unstable, caving or sloughing material is anticipated or encountered. Do not use drilling fluids to stabilize drill holes or remove cuttings.

(2) Soil Nail Bars

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

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

(3) Grouting

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

Place grout with a tremie in accordance with the contract and accepted submittals. Inject grout at the lowest point of drill holes through a tremie pipe, e.g., grout tube, casing, hollow-stem auger or drill rod, in one continuous operation. Fill

drill holes progressively from the bottom to top and withdraw tremie at a slow even rate as the hole is filled to prevent voids in the grout. Extend tremie pipe into grout a minimum of 5 ft (1.5 m) at all times except when grout is initially placed in a drill hole.

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

(4) Nail Heads

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

(D) Shotcreting

Perform shotcreting in accordance with the contract and accepted submittals. Use nozzlemen who made satisfactory preconstruction test panels.

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

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

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

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

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

(E) Soil Nail Testing

For this provision, “proof tests” are performed on test nails incorporated into the wall, i.e., production soil nails assuming test nails are acceptable in accordance with this provision. “Proof test nails” refer to soil nails on which proof tests are performed.

In general, proof tests on 5 percent of production soil nails with a minimum of 1 test per nail row is required. More or less soil nail testing may be required depending on the subsurface conditions encountered. The Engineer will decide the actual number and locations of proof tests.

Do not test soil nails until grout and shotcrete achieve the required 3 day compressive strength.

(1) Testing Equipment

Use testing equipment that includes the following.

- (a) 2 dial gauges with rigid supports
- (b) Hydraulic jack and pressure gauge
- (c) Jacking block or reaction frame

Use dial gauges capable of measuring to 0.001” (0.025 mm) and accommodating the maximum anticipated movement. Provide pressure gauges graduated in 100 psi (690 kPa) increments or less.

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

(2) Proof Tests

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

Soil nail bars for production soil nails may be overstressed under higher test nail loads. Use larger or higher grade steel bars to allow for higher loads instead of shortening bond lengths to less than the minimum.

Use the following equation to determine maximum bond lengths, L_B (ft or m).

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

where,

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

A_t = bar area (in² or m²),

f_y = bar yield stress (ksi or kPa) and

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

Use the following equation to determine design test loads, DTL (kips or kN).

$$DTL = L_B \times Q_{ALL}$$

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

Load	Hold Time
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	10 or 60 minutes (creep test)
AL*	1 minute

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

Reset dial gauges to zero after applying alignment load. Record test nail movement at each load increment and monitor test nails for creep at the 1.50 DTL load increment. Measure and record test nail movement at 1, 2, 3, 5, 6 and 10 minutes. When the test nail movement between 1 minute and 10 minutes exceeds 0.04" (1 mm), maintain the maximum test load for an additional 50 minutes and record movements at 20, 30, 50 and 60 minutes. Repump jack as needed to maintain the intended load during hold times.

(3) Test Nail Acceptance

Test nail acceptance is based on the following criteria.

- (a) Total creep movement is less than 0.04" (1 mm) between the 1 and 10 minute readings or less than 0.08" (2 mm) between the 6 and 60 minute readings and creep rate is linear or decreasing throughout the creep test load hold time.

- (b) Total test nail movement at maximum test load exceeds 80 percent of the theoretical elastic elongation of the test nail unbonded length.
- (c) Pullout failure does not occur at or before the 1.5 DTL load increment. Pullout failure is defined as the inability to increase the load while test nail movement continues. Record the pullout failure load as part of the test data.

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

(4) Test Nail Results

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

If the Engineer determines a test nail is unacceptable, either perform additional proof tests on adjacent production soil nails or revise the soil nail wall design for the production soil nails represented by the unacceptable proof test nail as determined by the Engineer. Submit a revised soil nail wall design for review and acceptance and provide an acceptable proof test nail with the revised design and/or installation methods at no additional cost to the Department. If required, remove representative production soil nails and/or provide new production soil nails with the revised design and/or installation methods at no additional cost to the Department.

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

8.0 MEASUREMENT AND PAYMENT

Shored Mechanically Stabilized Earth Retaining Walls will be measured and paid for in square feet (meters). SMSE walls will be measured as the exposed face area of the MSE wall with the wall height equal to the difference between the top and bottom of wall elevation. The top of wall elevation is defined as the top of coping unless shown otherwise on the plans. The bottom of wall elevation is defined as where the finished grade intersects the front face of the SMSE wall. No payment will be made for portions of SMSE walls below bottom of wall elevations or the Soil Nail Wall part of the SMSE wall.

The contract unit price bid for *SMSE Retaining Walls* will be full compensation for design, submittals, furnishing labor, tools, equipment and wall materials, excavating, backfilling, hauling and removing excavated materials and providing site assistance, leveling pads,

facing elements, reinforcement, select material, wall drainage systems, fabrics, coping, miscellaneous components, excavating, installing soil nails and geocomposite drain strips, grouting, testing nails, shotcreting including test panels and providing reinforcement and any incidentals necessary to design and construct SMSE walls in accordance with this provision.

No separate payment will be made for temporary shoring for wall construction. Temporary shoring for wall construction will be considered incidental to the contract unit price bid for *MSE Retaining Walls*.

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

Payment will be made under:

Pay Item

Shored Mechanically Stabilized Earth Retaining Walls

Pay Unit

Square Foot (Meter)

