**Special Note for Soil Nail Walls**

# DESCRIPTION

* 1. This work is for the design and construction of permanent “Soil Nail Walls". Use an approved Soil Nail Wall Contractor that has the expertise and capability to complete the work required by this Special Note. Only Contractors pre-qualified by the Kentucky Department of Highways (the Department) and that meet any specific requirements for this project may perform soil nail wall design and construction for this project.
	2. The contractor shall submit construction plans prepared by a soil nail wall contractor under the direction of the wall design Engineer to the project Engineer for review and approval.

# SCOPE OF WORK

* 1. The contract item "Soil Nail Wall" includes furnishing the materials, labor, tools, equipment, and other incidental items required for the design, construction, and testing of permanent soil nail walls as described herein.
	2. Soil nail wall construction includes excavating in staged lifts; drilling soil nail drillholes; providing, placing, and grouting the encapsulated or epoxy coated nail bar tendons into the drillholes; placing drainage elements; placing shotcrete reinforcement; applying shotcrete facing over the reinforcement; attaching bearing plates and nuts; performing nail testing; and installing permanent facing. Refer to Figure 2.1 in the FHWA Geotechnical Engineering Circular No. 7 "Soil Nail Walls" for the components of a soil nail wall.
	3. Soil nail wall construction may require excavation in staged lifts***. Excavation in the vicinity of the wall face requires special care and effort compared to general earthwork excavation and close coordination between the earthwork contractor and the Soil Nail Wall Contractor.*** The Prime Contractor should take this into account during bidding and should consult the Excavation Section of this Special Note and the Contract Plans for details.
	4. Subject to the requirements in the Contract Plans and this Special Note, select the method of excavation, drilling method and equipment, final drillhole diameter(s), and grouting procedures to meet the performance requirements specified herein.
	5. In design and construction of the wall, consider the potential risks involved due to slope failure. Excavation stability, slope stability, wall alignment, and wall stability are the Contractor's responsibilities from the beginning of work until final acceptance. Damage to property (public or private) or to the wall itself during construction is the responsibility of the Contractor. Analyze the soil nail wall system in order to ensure that the wall system will function as intended.

# The main body of this Special Note is general for permanent soil nail walls.

* 1. Construction Plans are defined as plans prepared by or for the Soil Nail Wall Contractor under the direction of the Wall Design Engineer and accepted by the Engineer for construction of the soil nail wall.

# REFERENCES

The documents below apply to this work. Unless noted otherwise, use the current edition as of the letting date of this project.

* 1. Contract Plans and Plan Notes
	2. The "Kentucky Standard Specifications for Road and Bridge Construction", Current Edition with supplements. This document may be referred to as "Specifications" or "Standard Specifications" elsewhere in this Special Note.
	3. The Department Manuals "Kentucky Methods", "List of Approved Materials", and "Field Sampling and Testing Practices".
	4. American Society for Testing and Materials (ASTM) Standards, Current Edition.
	5. American Association of State Highway and Transportation Officials (AASHTO) Standards, Current Edition.
	6. FHWA Publication FHWA-NHI-14-007, " Geotechnical Engineering Circular No. 7: Soil Nail Walls" (GEC No. 7), February 2, 2015.
	7. AASHTO LRFD Bridge Design Specifications, Current Edition, with all interims.
	8. AISC Steel Construction Manual for the design of structural hardware applies if the design is not covered in the AASHTO Standard Specifications for Highway Bridges, Current Edition, with all interims.

# EXPERIENCE REQUIREMENTS AND SUBMITTALS

Requirements for personnel experience and pre-construction submittals, **including submittal deadlines**, are in this section. Do not begin construction on any soil nail wall, other than stockpiling of wall materials, until the Engineer receives and accepts all submittals required in this section. Additional submittals and records required during and after construction may be included in other sections of this Special Note. The use of electronic submittals (.pdf format) will expedite the approval process.

* 1. Experience Requirements: The Department considers a satisfactory record of experience in soil nail wall design and construction important to successfully complete this work. Use personnel meeting the requirements below on this project and submit electronically in PDF format all information necessary to verify that they meet the requirements. **Submit this information no later than thirty (30) calendar days after receiving Notice to Begin Work.** As a minimum, include the following for each project necessary to satisfy the requirements:
1. The names and current phone numbers of the owner’s representative(s) who can verify that the Contractor meets the requirements.
2. The dates of construction.
3. The type (temporary/permanent) of structure.
4. The number of nails.
5. The maximum wall design height.

The Department will review the experience requirements and respond to the Contractor within twenty-one (21) calendar days. Review and acceptance by the Engineer is for evidence of the required experience and does not in any way relieve the Contractor of full responsibility for the successful and satisfactory completion of the work.

* 1. Contractor Experience Requirements The requirements for the Soil Nail Wall Contractor are:
		1. A minimum of five (5) years of experience constructing temporary and/or permanent soil nail retaining walls, with a minimum of three (3) projects and at least 600 soil nails or 15,000 ft2 of wall face completed in the past five (5) years.
		2. A minimum of three (3) soil nail retaining wall projects with permanent soil nail retaining walls at least 15 ft high completed in the past five (5) years, and at least 600 permanent soil nails or 15,000 ft2 of wall face completed in the past five (5) years.

Only drilled and grouted soil nails will satisfy these requirements. Some projects may be used to satisfy more than one requirement.

* 1. Personnel Experience Requirements
		1. Wall Design Engineer Experience Requirements

Use a Wall Design Engineer meeting the requirements below to assume full responsibility for soil nail wall design on this project. One or more other Engineers may assist with the design and plan preparation under the supervision of the Wall Design Engineer, who may be an employee of the Soil Nail Wall Contractor or a Consultant. However, manufacturers’ representatives may not be used to satisfy these requirements. The requirements for the Wall Design Engineer are:

* + - 1. Licensed Professional Engineer (Civil and/or Structural) in Kentucky.
			2. A minimum of five (5) years design and/or construction experience on temporary and/or permanent soil nail retaining walls, with experience on a minimum of three (3) projects and at least 600 soil nails or 15,000 ft2 of wall face, constructed in the past five (5) years.
		1. Project Engineer Experience Requirements

Use an engineer meeting the requirements below to have overall technical responsibility for soil nail wall construction on this project. It is not necessary for the Project Engineer to be on site on a daily basis. Consultants or manufacturers’ representatives may not be used to satisfy these requirements. The requirements for the Project Engineer are:

* + - 1. Licensed Professional Engineer in the U.S.
			2. A minimum of five (5) years design and/or construction experience on temporary and/or permanent soil nail retaining walls, with experience on a minimum of three (3) projects and at least 600 soil nails or 15,000 ft2 of wall face, constructed in the past five (5) years.
			3. An employee of the Soil Nail Wall Contractor.

The Project Engineer and the Wall Design Engineer may be the same person if that person meets all the stated requirements.

* + 1. On-Site Supervisor Experience Requirements

Use an on-site supervisor (project manager, superintendent, etc.) meeting the requirements below to be responsible for the daily soil nail wall construction activities on this project. Consultants or manufacturers’ representatives may not be used to satisfy the requirements of this section. The requirements for the On- Site Supervisor are:

* + - 1. A minimum of five (5) years construction experience on temporary and/or permanent soil nail retaining walls, with experience on a minimum of three (3) projects and at least 600 soil nails or 15,000 ft2 of wall face, constructed in the past five (5) years.
			2. An employee of the Soil Nail Wall Contractor.

The On-Site Supervisor and the Project Engineer may be the same person if that person meets all the stated requirements. The Department will consider allowing a team of more than one supervisor to satisfy these requirements and perform the associated functions, subject to certain conditions at the discretion of the Engineer. The Department may consider related experience with other similar types of specialty construction.

* + 1. Shotcrete Nozzlemen and Finishers Experience Requirements

Use shotcrete nozzlemen and finishers meeting the requirements below:

* + - 1. Certification in accordance with the ACI 506.3R “Guide to Certification of Shotcrete Nozzlemen” by an ACI recognized shotcrete testing lab and/or recognized shotcreting consultant and covering the type of shotcrete to be used (plain wet-mix, plain dry-mix or steel fiber reinforced). Provide proof of ACI certification.
			2. Experience with similar shotcrete application on at least three (3) projects constructed in the past five (5) years, with work totaling at least 5,000 square feet of area.
		1. The Engineer may suspend work on the wall if the Contractor substitutes unqualified and/or unapproved personnel or if the personnel are not performing the required duties. If work is suspended due to substitution of unqualified and/or unapproved personnel, the Contractor is fully liable for all costs resulting from the suspension of work. No adjustment in contract time resulting from this suspension of work will be allowed.
	1. Design Calculations and Construction Plans For each wall, submit electronically in PDF format for review Construction Plans and Design Calculations prepared by or under the supervision of the Wall Design Engineer and signed by the Wall Design Engineer. Submit in the same format revisions to construction plans and design calculations each time corrections are required. In the design calculations and construction plans, show explicit details sufficient to allow an expeditious review of the proposed design and construction procedures. Hard copies of the reviewed and accepted plans and calculations will be required as noted in Section 4.4.2. **Submit this information no later than sixty (60) calendar days after receiving Notice to Begin Work.**

Submit any changes or deviations from the Construction Plans for additional review and acceptance. No adjustments in contract time will be allowed due to incomplete submittals. Revise the drawings when plan dimensions are revised due to field conditions, evaluation of verification or proof test results, or for other reasons. Provide revised design calculations signed by the Wall Design Engineer for all design changes made during construction of the wall.

* + 1. Design Calculations: As a minimum, include the following items:
			1. A written summary report that describes the overall soil nail wall design.
			2. Applicable code requirements and design references.
			3. Nail wall critical design cross sections geometry including soil/rock strata and location, magnitude, and direction of the design slope or external surcharge loads and piezometric levels.
			4. Design criteria including, soil/rock shear strengths (friction angle and cohesion), unit weights, and ground-grout pullout resistances and nail drillhole diameter assumptions for each soil/rock strata.
			5. Partial safety factors/strength factors (for Service Load Design) used in the design on the pullout resistance, surcharges, soil/rock unit weights, nail head strengths, and steel, shotcrete, and concrete materials. Minimum required global stability soil factor of safety for SLD design.
			6. Seismic design acceleration coefficient.
			7. Design calculation sheets with the project number, wall location, designation, date of preparation, initials of designer and checker, and page number at the top of each page. Provide an index page with the design calculations.
			8. Design notes including an explanation of any symbols and computer programs used in the design.
			9. Nail wall final design cross-sections geometry including soil/rock strata and location, magnitude, and direction of slope or external surcharge loads and piezometric levels with critical slip surface shown along with minimum calculated Global stability soil factor of safety of SLD design and required nail lengths and strengths (nail bar sizes and grades) for each nail row.
			10. Structural design calculations for wall facings and nail head/facing connections including consideration of facing flexural and punching shear strength, headed studs tensile strength, upper cantilever, minimum reinforcement ratio, cover and splice requirements.
			11. Any other necessary design calculations.
		2. Construction Plans: As a minimum, include the following items:
			1. A natural scale plan view of the wall identifying:
				1. A reference baseline and north arrow.
				2. The offset and offset from the construction centerline or baseline to the face of the wall at its base at all changes in horizontal alignment.
				3. Beginning and end of wall stations and offsets.
				4. Right-of-way and permanent or temporary construction easement limits, location of all known active and abandoned existing utilities, adjacent structures, or other potential interferences. The centerline of any drainage structure or drainage pipe behind, passing through or passing under the wall.
				5. Limits of longest nails.
				6. Subsurface exploration locations shown on a plan view of the proposed wall alignment with appropriate references base lines to fix the locations of the explorations relative to the wall.
			2. A natural scale elevation view of the wall identifying:
				1. The elevation at the top of the wall, at all horizontal and vertical break points, and at least every 25 ft. along the wall.
				2. Elevations at the wall base and the top of leveling pads for casting CIP facing (if applicable).
				3. Beginning and end of wall stations and stations of alignment breaks.
				4. The distance along the face of the wall to all steps in the wall base.
				5. Wall elevation view showing nail locations and elevations; vertical and horizontal nail spacing; and the location of wall drainage elements and permanent facing expansion/contraction joints (if applicable) along the wall length.
				6. Existing and finish grade profiles both behind and in front of the wall.
				7. Elevation Datum
			3. Design parameters, including ultimate and allowable nail pullout resistance.
			4. General notes for constructing the wall including construction sequencing or other special construction requirements.
			5. Horizontal and vertical curve data affecting the wall and wall control points. Match lines or other details to relate wall station to centerline stationing.
			6. A summary of quantities of each wall showing estimated square feet of wall face.
			7. Nail wall typical section including staged excavation lifts, wall and excavation face batter, nail spacing and inclination, nail bar sizes, and corrosion protection details.
			8. A typical detail of production and test nails defining the nail length, minimum drillhole diameter, inclination, test nail bonded and unbonded test lengths and Design Test Loads (DTL’s).
			9. A soil nail schedule including:
				1. Soil nail numbers
				2. Soil nail design loads
				3. Type, size, and number of bars
				4. Total nail lengths
				5. Nail hole diameters
				6. Angle of nail inclination
				7. Nail locations and spacing
			10. Details, dimensions, and schedules for all nails, reinforcing steel, wire mesh, bearing plates, headed studs, etc. and/or attachment devices for shotcrete, cast-in-place, or prefabricated facings.
			11. Dimensions and schedules of all reinforcing steel including reinforcing bar bending details.
			12. Details and dimensions for wall appurtenances such as barriers, coping, drainage gutters, fences, etc.
			13. Details for constructing wall around drainage facilities.
			14. Details for terminating wall and adjacent slope construction.
			15. Facing finishes, color, and architectural treatment requirements (if applicable) for permanent wall facing details.

The Department will complete the review within thirty (30) calendar days of each submittal; the Department will not suspend charging working days for this review period. Insufficient design and/or plan details, as judged by the Engineer, will be cause for withholding acceptance. The Contractor is fully liable for all costs resulting from acceptance being withheld; the Department will not suspend charging working days as the result of not accepting the design, details, or plans. Review and acceptance of the plans by the Engineer is for evidence of work to be performed and does not in any way relieve the Contractor of full responsibility for the design and for successful and satisfactory completion of the work.

After the review is completed and the Engineer accepts the Design Calculations and Construction Plans, furnish the Resident Engineer, ten (10) full sets of accepted Final Construction Plans for the Department's use, and four (4) sets of accepted Final Design Calculations. Submit design calculations and construction plans stamped and signed by the Soil Nail Wall Design Engineer. Provide a set of the above information electronically in PDF format

* 1. Construction and Materials Submittals **Submit the below information no later than sixty (60) calendar days after receiving Notice to Begin Work and thirty (30) calendar days prior to beginning wall construction.** Submit electronically in PDF format the following:
		1. The proposed start date and proposed wall construction sequence and schedule including:
			1. Plan describing how surface water will be diverted, controlled, and disposed of.
			2. Proposed methods and equipment for excavating the soil and/or rock to the staged excavation lifts, including the proposed grade elevations for each excavation lift.
			3. Measures to ensure wall and slope stability during various stages of wall construction and excavation where discontinuous rows of nails will be installed (if applicable); information on space requirements for installation equipment; temporary shoring plans (if applicable); information on provisions for working in the proximity of underground facilities or utilities (if applicable).
			4. Proposed nail drilling and grouting methods and equipment including drillhole diameter proposed to achieve the required pullout resistance values and any variation of these along the wall alignment.
		2. Grout submittal, including:
			1. type of mixer
			2. water/cement ratio
			3. type of additives
			4. design grout pressure
			5. type of cement
			6. quantity of fly ash
			7. mix design
			8. design strength of grout
			9. mix verification testing
		3. Certified mill test results for nail bars and couplers from each heat specifying the ultimate strength, yield strength, elongation, and composition.
		4. Certificates of Compliance for the following materials, if used. Provide certificates stating that the material or assemblies to be provided will fully comply with the contract requirements:
			1. Nail Centralizers
			2. Nail Encapsulation
			3. Bearing Plates
			4. Nuts
			5. Portland Cement
			6. Documentation to support any other requirements in the Materials Section of this Special Note
		5. Shotcrete and Drainage submittals including:
			1. Proposed methods of shotcrete placement and of controlling and maintaining facing alignment and location and shotcrete thickness.
			2. Shotcrete mix design performed by a certified ACI Level II or KRMCA Level II technician including:
				+ Type of Portland cement.
				+ Aggregate source and gradation.
				+ Proportions of mix by weight and water-cement ratio.
				+ Proposed admixtures, manufacturer, dosage, and technical literature.
				+ If prepackaged shotcrete is used, previous strength test results for the same shotcrete mix from the same manufacturer completed within one year of the start of shotcreting may be submitted for initial verification of the required compressive strengths at start of production work.
			3. Certificates of Compliance, manufacturers' engineering data and installation instructions for the PVC drain piping, drainage geotextile, geocomposite drain strip, drain grate, and accessories.
		6. Proposed nail testing methods and equipment setup including:
			1. Details of the jacking frame and appurtenant bracing.
			2. Details showing methods of isolating test nails during shotcrete application (i.e., methods to prevent bonding of the soil nail bar and the shotcrete facing during testing).
			3. Details showing methods of providing the temporary unbonded length and of grouting the temporary unbonded length of test nails after completion of testing.
			4. Specific test nail locations including stations and elevations.
			5. Equipment list.
			6. Identification number and certified calibration records for each test jack and pressure gauge (calibrated as a unit no more than 12 months prior to use) and load cell to be used.
		7. Instrumentation submittals, if required.
		8. Any other documentation required to verify that proposed construction procedures and materials fully comply with all requirements in the contract documents.

The Department will complete the review within thirty (30) calendar days after accepting the Design Calculations and Construction plans or within thirty (30) calendar days after receiving each submittal; the Department will not suspend charging working days for this review period. Unacceptable methods or documentation, as judged by the Engineer, will be cause for withholding acceptance. The Contractor is fully liable for all costs resulting from acceptance being withheld; the Department will not suspend charging working days as the result of not accepting the design, details, or plans. Review and acceptance by the Engineer is for evidence of work to be performed and does not in any way relieve the Contractor of full responsibility for the successful and satisfactory completion of the work.

* 1. Soil Nail Wall Pre-Construction Meeting A Pre-Construction Meeting to discuss soil nail wall construction will be required. This meeting will be held after all soil nail submittals in Sections 4.1, 4.2, 4.3, and 4.4 have been received, reviewed, and accepted by the Department, after the submittals in Section 4.5 have been received by the Department, and at least ten (10) working days prior to the beginning of soil nail construction. The purpose of the meeting is to discuss construction procedures, personnel, and equipment to be used. The following will be expected to attend:
* Representing the Contractor and Subcontractors - Prime Contractor Representative, Soil Nail Wall Design Engineer, Soil Nail Wall Project Engineer, and Soil Nail Wall On-Site Supervisor. Also, representatives of the Excavation Contractor, Shotcreting Contractor, and Surveyor, if different than the Prime or Soil Nail Wall Contractor.
* Representing the Quality Control Team - QCP Manager and Lead Inspector.
* Representing the Department - Section Engineer, Central Office Construction Engineer, Geotechnical Branch Representative, and others as deemed appropriate by the Section Engineer.

If the Contractor’s key personnel change or if the Contractor proposes a significant revision to soil nail construction procedures, additional Soil Nail Pre- Construction meetings may be required at the discretion of the Engineer.

# DESIGN

Design the soil nail wall using the Allowable Stress Design (ASD) method, also known as Service Load Design (SLD). Primary design references include but are not limited to: FHWA Publication FHWA-NHI-14-007, "Geotechnical Engineering Circular No.7, Soil Nail Walls”, February 2, 2015; AASHTO Standard Specifications for Highway Bridges, Current Edition, with all interims. Use required partial safety factors, allowable strength factors, and minimum global stability soil factors of safety in accordance with the FHWA GEC No. 7, unless specified otherwise; critical structure requirements apply. Perform structural design of any individual wall elements not covered in FHWA GEC No. 7 by the Service Load Design methods in conformance with appropriate articles of the AASHTO Specifications. Estimated soil/rock design shear strength parameters, slope and external surcharge loads, type of wall facing and facing architectural requirements, soil nail corrosion protection requirements, known utility locations, easements, and right- of-ways will be as shown in the Contract Plans or specified elsewhere in this Special Note.

Refer to the Contract Plans for additional information to be used for the design of the soil nail wall, including: Wall Plan and Elevation Views, Soil Nail Wall Details, and Subsurface Data.

* 1. Soil Nail Capacity Determine the allowable pullout resistance necessary to develop the required design loads using theoretical and empirical methods and based on evaluation of the subsurface data in the Contract Plans and/or inspection of the site. Verify the desired soil nail capacities in accordance with the Soil Nail Testing and Acceptance Section of this Special Note.
	2. Soil Nail Geometry
		+ Unless specified in the Contract Plans or elsewhere in this Special Note, provide a minimum soil nail length of 10 ft.
		+ Provide a minimum nail hole diameter of 6 inches.
		+ Provide a nail inclination of at least 10o but no more than 20o, unless otherwise specified in the Contract Plans or elsewhere in the Special Note.
		+ Do not extend the nails beyond the right-of-way or easement limits shown in the Contract Plans.
	3. Corrosion Protection Provide design and details for Class I Protection in accordance with FHWA GEC No. 7 (Sections C.3 and C.4), except that the required thickness of bar-coating epoxy is 7-12 mils rather than 16 mils.
	4. Structural Hardware Design structural hardware in accordance with the current edition of the AISC Steel Construction Manual and the current edition of the AASHTO Standard Specifications for Highway Bridges with interims. Where these conflict, AASHTO Specifications with interims govern.
	5. Temporary Shotcrete and Wall Drainage Design a temporary shotcrete and permanent wall drainage system as shown in the Contract Plans and/or specified elsewhere in this Special Note. The Wall Design Engineer is responsible for providing all necessary details required to successfully construct the temporary shotcrete facing and wall drainage system (including weep drains and/or toe drains as applicable) to satisfy the design intent of the wall. Comply with AASHTO Specifications or the FHWA GEC No. 7 for any specific items that may not be addressed herein or elsewhere in the Contract Documents.
	6. Wall Alignment Ensure that the wall is compatible with the horizontal and vertical alignment indicated in the Contract Plans. Survey control is the front face of the wall.
	7. Permanent Concrete Facing When permanent concrete facing is required, provide cast-in-place concrete facing unless otherwise specified in the plans. Refer to the plans for detail concerning formliners or other architectural treatments that may be required. Design concrete facing for full loads at final condition (in-place facing and complete construction). Provide a minimum facing thickness according to the following:

|  |  |
| --- | --- |
| Cast-in-Place Concrete with 1 Mat of Reinforcement | 10 inches |
| Cast-in-Place Concrete with 2 Mats of Reinforcement | 12 inches |

The minimum concrete cover over reinforcement is 3 inches against temporary shotcrete and 2 inches on the front face. Provide joints and joint materials as shown in the Contract Plans.

Protrusions beyond the face of the wall are not allowed. Completely fill any voids between the permanent facing and the construction facing with grout.

Include details for formwork connections to the shotcrete facing and/or nails (if applicable), proposed concrete placement method and placement rates, and accompanying structural calculations verifying the structural adequacy of the formwork, connections, and shotcrete facing and/or nails to support the loading induced by the fluid CIP concrete. When anchors embedded into the shotcrete facing will be used to support the 1-sided CIP face form, include calculations illustrating the anchor design load (calculated as the design concrete fluid pressure times the anchor tributary area).

* 1. Surface Drainage Coordinate design of surface drainage above the walls with the wall design.

# MATERIALS

Provide materials conforming to the requirements below when the materials are required by the Contract Plans, this Special Note, the Construction Plans, or elsewhere in the Contract Documents.

* 1. Soil Nails
		1. Solid Bar Nails AASHTO M31/ASTM A615, Grade 60 or 75, ASTM A722 for Grade 150. Deformed bar, continuous without splices or welds, new, straight, undamaged, and encapsulated. Threaded a minimum of 6 inches on the wall anchorage end to allow proper attachment of bearing plate and nut. Threading may be continuous spiral deformed ribbing provided by the bar deformations (e.g. continuous threadbars) or may be cut into a reinforcing bar. If threads are cut into a reinforcing bar, provide the effective area used for design, at no additional cost. Use mechanical splicers only for nails greater than 40 ft. in length.
		2. Bar Couplers Bar couplers that develop the full ultimate tensile strength of the bar as certified by the manufacturer.
		3. Fusion Bonded Epoxy Coating ASTM A 775, 7-12 mil thickness electrostatically applied. Bend test requirements are waived. Coating at the wall anchorage end of epoxy-coated bars may be omitted over the length provided for threading the nut against the bearing plate.
		4. Encapsulation Minimum 40 mils thick corrugated HDPE tube conforming to AASHTO M252 or corrugated PVC tube conforming to ASTM D1784, Class 13464-B.
	2. Soil Nail Appurtenances
		1. Centralizers Manufactured from Schedule 40 PVC pipe or tube, steel, or other material not detrimental to the nail steel (do not use wood); securely attached to the nail bar; sized to position the nail bar within 1 inch of the center of the drillhole; sized to allow tremie pipe insertion to the bottom of the drillhole; and sized to allow grout to freely flow up the drillhole.
		2. Nail Grout Provide Type I or III Portland Cement conforming to ASTM C 150 and Section 801 of the Standard Specifications. Provide fresh cement that does not contain any lumps or other indication of hydration or “pack set.” Provide water in the grout that is potable, clean, and free of injurious substances, and meets the requirements of Section 803 of the Standard Specifications, except that the chloride content of the water does not exceed 100 ppm.

 Provide grout consisting of a pumpable neat mixture of cement and water and is stable (bleed less than 2 percent), fluid, with a minimum 28-day compressive strength of 2000 psi and 1000 psi at 3 days, measured in accordance with ASTM C 109. No later than thirty days prior to beginning grouting operations, submit to the Engineer results of tests performed by an approved laboratory which demonstrate that the proposed grout mixture meets the requirements of this note. Include a graph with this information relating compressive strength of the grout to age covering a range of ages from 24 hours to 28 days.

 Add water to the mixer first followed by cement and the admixtures. Mix the grout in mechanical mixing equipment of a type capable of continuous mixing which produce a grout free of lumps and undispersed cement. Auger mixing of the grout is not permitted. Retempering to the grout is not permitted.

|  |
| --- |
| **Required Grout Physical Properties** |
| **Property** | **Test****Value** | **Test****Method** |
| Water-Cement Ratio | Max. 0.45 | ------------------- |
| 28 Day Compressive Strength (Average of 3 cubes) | Min. 2000 psi | ASTM C109 |
| 3 Day Compressive Strength (Average of 3 cubes) | Min. 1000 psi | ASTM C109 |
| Expansion | 0.5% min2% max | ASTM C1090 |

* + 1. Admixtures Section 802 of the Standard Specifications. Admixtures which control bleed, improve flowability, reduce water content and use retard set in the grout, subject to review and acceptance by the Engineer. Accelerators are not permitted. Expansive admixtures may only be used in grout used for filling sealed encapsulations. Use admixtures compatible with the grout and mixed in accordance with the manufacturer’s recommendations.
		2. Film Protection Polyethylene film per AASHTO M171.
	1. Bearing Plates, Nuts, and Welded Stud Shear Connectors
		1. Bearing Plates ASTM A36
		2. Nuts AASHTO M291, Class B, hexagonal, fitted with beveled washer or spherical seat to provide uniform bearing.
		3. Shear Connectors AASHTO Construction Specifications, Section 11.3.3.1
	2. Temporary Shotcrete and Wall Drainage Materials Deliver, store and handle materials to prevent contamination, segregation, corrosion, or damage. Store liquid admixtures to prevent evaporation and freezing.

Provide drainage geotextile and geocomposite drain strips in rolls wrapped with a protective covering and stored in a manner which protects the fabric from mud, dirt, dust, debris, and shotcrete rebound. Do not remove protective wrapping until immediately before the geotextile or drain strip is installed. Avoid extended exposure to ultra-violet light. Label each roll of geotextile or drain strip in the shipment to identify the production run.

|  |
| --- |
| **Section References are in the Kentucky Standard Specifications, Current Edition** |
| Cement | Section 801, Type I, II, III or IV |
| Fine Aggregate | Section 804, Concrete Sand |
| Coarse Aggregate | Section 805, No. 11 |
| Water | Section 803 |
| Chemical Admixtures: |  |
| Accelerator | Section 802, Fluid type, applied at nozzle |
| Water-reducer and Superplastisizer | Section 802 |
| Retarders | Section 802 |
| Mineral Admixtures: |  |
| Fly Ash | Section 844, Cement replacement up to 35% by weightof cement |
| Silica Fume | Section 844, 90% minimum silicon dioxide solidscontent, not to exceed 12% by weight of cement |
| Welded Steel Wire Fabric | Section 811/AASHTO M55 |
| Reinforcing Bars for Shotcrete Facing | Section 811, Grade 60, deformed |
| Bearing Plates | ASTM A36 |
| Nuts | AASHTO M291, Class B, hexagonal, fitted with beveledwasher or spherical seat to provide uniform bearing |
| Prepackaged Shotcrete | ASTM C928 |
| Toe Drain Geotextile | Section 843, Type II |
| Drainage Aggregate | Section 805.08, with no more than 2% passing the No.200 sieve |
| Geocomposite Drain Strip | Amerdrain 500 or approved equal |
| Film Protection | Polyethylene films per AASHTO M-171 |
| PVC Connector and Drain Pipes: |  |
| Pipe | ASTM 1785 Schedule 40 PVC, solid and perforated wall,cell classification 12454-B or 12354-C, wall thickness SDR 35, with solvent weld or elastomeric gasket joints |
| Fittings | ASTM D3034, cell classification 12454-B or 12454-C,wall thickness SDR35, with solvent weld or elastomeric gasket joints |
| Solvent Cement | ASTM D2564 |
| Primer | ASTM F656 |

* + 1. Shotcrete Mix Design Use shotcrete complying with the requirements of ACI 506.2, "Specifications for Materials, Proportioning and Application of Shotcrete", except as otherwise specified. The Contractor must receive notification from the Engineer that the proposed mix design and method of placement are acceptable before shotcrete placement can begin.
			1. Proportioning and Use of Admixtures Proportion the shotcrete to be pumpable with the concrete pump furnished for the work, with a cementing materials content of at least 24.3 lb/cy and water/cement ratio not greater than 0.50. Do not use admixtures unless approved by the Engineer. Thoroughly mix admixtures into the shotcrete at the rate specified by the manufacturer. Use only accelerators compatible with the cement used, non-corrosive to steel, and not promoting other detrimental effects such as cracking or excessive shrinkage. The maximum allowable chloride ion content of all ingredients is 0.10% when tested to AASHTO T260.
			2. Air Entrainment Air entrainment is not required for temporary shotcrete construction facings.
			3. Strength Requirements Provide shotcrete with a compressive strength of 2000 psi in 3 days and 4000 psi in 28 days. The average compressive strength of each set of three test cores extracted from test panels or wall face must equal or exceed 85 percent of the specified compressive strength, with no individual core less than 75 percent of the specified compressive strength, in accordance with ACI 506.2.
			4. Mixing and Batching Batch aggregate and cement by weight or by volume in accordance with the requirements of ASTM C94 or AASHTO M241/ASTM C685. Use mixing equipment that thoroughly blends the materials in sufficient quantity to maintain placing continuity. Produce ready mix shotcrete complying with AASHTO M157. Batch, deliver, and place shotcrete within 90 minutes of mixing. The use of retarding admixtures may extend application time beyond 90 minutes if approved by the Engineer.

Premixed and packaged shotcrete mix may be provided for on-site mixing. Use packages containing materials conforming to the Materials Section. Placing time limit after mixing is per the manufacturers’ recommendations.

* + 1. Field Quality Control Production test panels or test cores from the wall facing are required. Perform shotcreting and coring of test panels using qualified personnel in the presence of the Engineer. Provide equipment, materials, and personnel as necessary to obtain shotcrete cores for testing including construction of test panel boxes, field curing requirements and coring. Shotcrete final acceptance will be based on the 28-day strength.

Begin shotcrete production work only upon initial approval of the design mix and nozzlemen and continue if the specified strengths are obtained. The shotcrete work by a crew will be suspended if the test results for their work do not satisfy the strength requirements. Change all or some of the following: the mix, the crew, the equipment, or the procedures. Before resuming work, the crew must shoot additional test panels and demonstrate that the shotcrete in the panels satisfies the specified strength requirements. Provide all work required to obtain satisfactory strength tests at no additional cost to the Department.

* + - 1. Production Test Panels Furnish at least one production test panel or, in lieu of production test panels, six 3-inch diameter cores taken from the shotcrete facing, during the first production application of shotcrete and henceforth for every 5000 ft2 of shotcrete placed. Construct the production test panels simultaneously with the shotcrete facing installation at times designated by the Engineer. Make production test panels with minimum dimensions of 18x18inches square and at least 4 inches thick.
			2. Test Panel Curing, Test Specimen Extraction and Testing

Immediately after shooting, field moist cure the test panels by covering and tightly wrapping with a sheet of material meeting the requirements of ASTM C171 until they are delivered to the testing lab or test specimens are extracted. Do not immerse the test panels in water. Do not further disturb test panels for the first 24 hours after shooting. Provide at least six 3-inch diameter core samples cut from each preconstruction test panel and production test panel. Contractor has the option of extracting test specimens from test panels in the field or transporting to another location for extraction. Keep panels in their forms when transported. Do not take cores from the outer 6 inches of test panels measured in from the top outside edges of the panel form. Trim the ends of the cores to provide test cylinders at least 3 inches long. If the Contractor chooses to take cores from the wall face in lieu of making production test panels, the Engineer will designate locations. Clearly mark the cores and container to identify the core locations and whether they are for preconstruction or production testing. If for production testing, mark the section of the wall represented by the cores on the cores and container. Immediately wrap cores in wet burlap or material meeting requirements of ASTM C171 and seal in a plastic bag. Deliver cores to the testing lab within 48 hours of shooting the panels. The remainder of the panels will become the property of the Contractor. Upon delivery to the testing lab, place the samples in the moist room until the time of test. When the test length of a core is less than twice the diameter, apply the correction factors given in AASHTO T24/ASTM C42 to obtain the compressive strength of individual cores. Test three cores will be tested at 3 days and three cores at 28 days in accordance with AASHTO T24/ASTM C42.

Fill core holes in the wall by dry-packing with non-shrink patching mortar after the holes are cleaned and dampened. Do not fill core holes with shotcrete.

* 1. Permanent Concrete Facing
		1. Cast-in-Place Concrete Conform to the Standard Specifications for Class A concrete.
		2. Precast Concrete Panels Conform to the Standard Specifications for Class D or Class D Modified concrete. Obtain panels from an approved Precast Concrete Producer on the KYTC List of Approved Materials.
		3. Reinforcing Steel Conform to the Standard Specifications. Epoxy coating is not required.
	2. Materials Handling and Storage Comply with the Standard Specifications and the items below:
1. Do not move or transport encapsulated nails until the encapsulation grout has reached sufficient strength to resist damage during handling.
2. Handle encapsulated nails in a manner that will prevent large deflections, distortions, or damage.
3. Repair encapsulated nails that are damaged or defective in accordance with the manufacturer's recommendations or remove them from the site.

# MATERIALS TESTING AND ACCEPTANCE

* 1. Materials Sampling and Testing will be in accordance with Section 106 of the Standard Specifications, the Department’s current "Kentucky Methods", the current "Manual of Field Sampling and Testing Practices", and other referenced documents.
	2. Use only materials accepted by the Department before use. The Engineer may suspend work on the wall if the Contractor does not have acceptance of materials to be used and there is no other work on the wall that may be done. If work is suspended due to lack of material acceptance, the Contractor is fully liable for additional cost from the suspension of work. No additional contract time resulting from the suspension of work will be allowed.

# CONSTRUCTION

Construct the wall(s) according to the Contract Plans, Construction Plans, the Standard Specifications, and the requirements below. In all cases, provide materials conforming to the Materials Section of this Special Note.

* 1. Excavation ***Coordinate the work and the excavation so the soil nail wall is safely constructed.*** Perform the wall construction and excavation sequence in accordance with the Construction Plans. Proceed with excavation in stages exposing the minimum amount of soil or rock face that will allow the practical and expeditious application of the shotcrete and the installation of soil nails while assuring stability of the excavated face and minimizing ground movements. Excavate a neat line face to facilitate application of temporary shotcrete and limit excavation in front of walls to 2 ft. below any soil nail until that nail has been completed and tested (if applicable). Leave temporary excavation lifts open no more than 24 hours without the temporary shotcrete facing or nails installed. After temporary shotcrete has been applied, excavate the next lift only after the shotcrete strength reaches 2000 psi.
	2. Drilling Drill holes for soil nails at the locations shown in the Construction Plans. Use drilling methods and soil nail lengths necessary to develop adequate load capacity to satisfy testing acceptance criteria for the design load required, but not less than the lengths and diameters shown on the Construction Plans. It is the Contractor’s responsibility to choose drilling methods that will maintain open drill holes and that do not promote mining or loosening of the soil at the perimeter of the drill hole or fracture soil with weak stratification planes by use of high flush volumes and pressures. At the ground surface, locate the drill hole within 6 inches of the location shown on the Construction Plans. At the point of entry, angle the nail within plus or minus 3o of that shown on the Construction Plans. Do not extend the nails beyond the right-of-way or easement limits shown in the Contract Plans provided in the contract documents.
	3. Nail Installation Place centralizers as shown in the Construction Plans as necessary for corrosion protection.
	4. Grouting Provide grouting equipment capable of continuous mixing and producing a grout free of lumps. Place nails in each drilled hole either prior to grouting or within 15 minutes of the grout injection. Grout until the hole is completely filled with grout and clean grout is seen to run from the top of the hole. Accomplish mortar packing and secondary grouting to the wall face as soon as practical after nail installation. Provide secondary grouting to the small ungrouted zone at the face and place a bearing plate over the bar and dry pack with cement or a cement mortar to provide even bearing against the shotcrete face.

Test grout according to AASHTO T106/ASTM C109 at a frequency of no less than one test every 50 CY of grout placed. Provide grout cube test results to the Engineer within 24 hours of testing.

* 1. Temporary Shotcrete and Wall Drainage Shotcrete facing and wall drainage work consists of furnishing all materials and labor required for placing and securing geocomposite drainage material, connection pipes, weepholes and horizontal drains (if required), drainage gutter, reinforcing steel and shotcrete for the temporary shotcrete construction facing and nail head bearing plates and nuts for the soil nail walls. The Work includes any preparatory trimming and cleaning of soil/rock surfaces and shotcrete cold joints to receive new shotcrete.

Use shotcrete complying with the requirements of ACI 506.2, "Specifications for Materials, Proportioning and Application of Shotcrete," except as otherwise specified. Shotcreting consists applying of one or more layers of concrete conveyed through a hose pneumatically projected at a high velocity against a prepared surface.

Produce shotcrete by either a wet-mix or dry-mix process. The wet-mix process consists of thoroughly mixing all the ingredients except accelerating admixtures, but including the mixing water, introducing the mixture into the delivery equipment and delivering it, by positive displacement, to the nozzle. Air jet the wet-mix shotcrete from the nozzle at high velocity onto the surface. The dry-mix process consists of shotcrete without mixing water that is conveyed through the hose pneumatically with the mixing water introduced at the nozzle. For additional descriptive information, refer to the American Concrete Institute ACI 506R "Guide to Shotcrete."

All temporary shotcrete and wall drainage construction is incidental to the Contract Unit Bid Price for “Soil Nail Wall” per “Square Foot”.

* 1. Wall Drainage Network Install and secure all elements of the wall drainage network as shown in the Construction Plans, specified herein, or as required to suit the site conditions. Install geocomposite drain strips and PVC connection pipes as shown on the Construction Plans. Install all elements of the drainage network prior to shotcreting. Capture unanticipated subsurface drainage features exposed in the excavation cut face independently of the wall drainage network and mitigate prior to shotcrete application.
		1. Geocomposite Drain Strips Install geocomposite drain strips centered between offset nail columns as shown in the Construction Plans. The maximum horizontal spacing between drain strips is 5 feet. Use drain strips at least 12 inches wide and place the geotextile side against the ground. Secure the strips to the excavation face and prevent shotcrete from contaminating the ground side of the geotextile. Install vertically continuous drain strips. Make splices with a 12-inch minimum overlap such that the flow of water is not impeded. Repair damage to the geocomposite drain strip, which may interrupt the flow of water.
		2. Toe Drains If required, install toe drains at the bottom of each wall. Wrap the drainage geotextile around the toe drain aggregate and pipe and conform to the dimensions of the trench. Conform to Section 214 of the Standard Specifications for Geotextile Construction. Overlap the drainage geotextile on top of the drainage aggregate as shown in the Construction Plans. Replace or repair damaged or defective drainage geotextile.
		3. Connection Pipes and Weepholes Install connection pipes as shown in the Construction Plans. Connection pipes are lengths of solid PVC pipe installed to direct water from the geocomposite drain strips to the exposed face of the wall. Connect the connection pipes to the drain strips using either prefabricated drain grates as shown in the Construction Plans or using the alternate connection method described below. Install the drain grate per the manufacturer's recommendations. Seal the joint between the drain grate and the drain strip and the discharge end of the connector pipe to prevent shotcrete intrusion.

The alternative acceptable method for connection of the connector pipe to the drain strip involves cutting a hole slightly larger than the diameter of the pipe into the strip plastic core but not through the geotextile. Wrap both ends of the connection pipe in geotextile in a manner that prevents migration of fines through the pipe. Tape or seal the inlet end of the pipe where it penetrates the drain strip and the discharge end of the connector pipe in a manner that prevents penetration of shotcrete into the drain strip or pipe. To assure passage of groundwater from the drain strip into the connector pipe, slot the inlet end of the connector pipe at every 45 degrees around the perimeter of the pipe to a depth of ¼ inch.

Provide weepholes, if required, through the construction facing to drain water from behind the facing. Install as shown in the Construction Plans. Use PVC pipe to form the weephole through the shotcrete. Cover the end of the pipe contacting the soil with a drainage geotextile. Prevent shotcrete intrusion into the discharge end of the pipe.

* 1. Temporary Shotcrete Construction Facing
		1. Shotcrete Alignment and Thickness Control Ensure that the minimum thickness of shotcrete that shown in the Construction Plans, using shooting wires, thickness control pins, or other devices acceptable to the Engineer. Install thickness control devices normal to the surface such that they protrude the required shotcrete thickness outside the surface. Ensure that the front face of the shotcrete does not extend beyond the limits shown in the Construction Plans.
		2. Surface Preparation Clean the face of the excavation and other surfaces to be shotcrete of loose materials, mud, rebound, overspray or other foreign matter that could prevent or reduce shotcrete bond. Protect adjacent surfaces from overspray during shooting. Avoid loosening, cracking, or shattering the ground during excavation and cleaning. Remove any surface material that is so loosened or damaged, to a sufficient depth to provide a base that is suitable to receive the shotcrete. Remove material that loosens as the shotcrete is applied. The cost of additional shotcrete is incidental to the work. Divert water flow and remove standing water so that shotcrete placement will not be detrimentally affected by standing water. Do not place shotcrete on frozen surfaces.
		3. Delivery and Application Maintain a clean, dry, oil-free supply of compressed air sufficient for maintaining adequate nozzle velocity at all times. Use equipment capable of delivering the premixed material accurately, uniformly, and continuously through the delivery hose. Control shotcrete application thickness, nozzle technique, air pressure, and rate of shotcrete placement to prevent sagging or sloughing of freshly applied shotcrete.

Apply the shotcrete from the lower part of the area upward to prevent accumulation of rebound. Orient nozzle at a distance and approximately perpendicular to the working face so that rebound will be minimal and compaction will be maximized. Pay special attention to encapsulating reinforcement. Do not work rebound back into the construction. Where shotcrete is used to complete the top ungrouted zone of the nail drill hole near the face, position the nozzle into the mouth of the drillhole to completely fill the void.

A clearly defined pattern of continuous horizontal or vertical ridges or depressions at the reinforcing elements after they are covered with shotcrete will be considered an indication of insufficient reinforcement cover or poor nozzle techniques. In this case immediately suspend the application of shotcrete and implement corrective measures before resuming the shotcrete operations. Correct the shotcreting procedure by adjusting the nozzle distance and orientation, by ensuring adequate cover over the reinforcement, by adjusting the water content of the shotcrete mix or other means. Adjustment in water content of wet-mix will require requalifying the shotcrete mix.

* + 1. Defective Shotcrete Repair shotcrete surface defects as soon as possible after placement. Remove and replace shotcrete that exhibits segregation, honeycombing, lamination, voids, or sand pockets. In-place shotcrete not meeting the specified strength requirement will be subject to remediation. Possible remediation options include placement of additional shotcrete thickness or removal and replacement, at no additional cost to the Department.
		2. Construction Joints Taper construction joints uniformly toward the excavation face over a minimum distance equal to the thickness of the shotcrete layer. Provide a minimum reinforcement overlap at reinforcement splice joints as shown in the Construction Plans. Clean and wet the surface of a joint before adjacent shotcrete is applied. Where shotcrete is used to complete the top ungrouted zone of the nail drill hole near the face, to the maximum extent practical, clean and dampen the upper grout surface to receive shotcrete, similar to a construction joint.
		3. Finish Use either an undisturbed gun finish as applied from the nozzle or a rough screeded finish. Remove shotcrete extending into the CIP finish face section beyond the tolerances specified herein.
		4. Attachment of Nail Head Bearing Plate and Nut Attach a bearing plate and nut to each nail head as shown on the Construction Plans. While the shotcrete is still plastic and before its initial set, uniformly seat the plate on the shotcrete by hand wrench tightening the nut. Where uniform contact between the plate and the shotcrete cannot be provided, set the plate in a bed of grout. After grout has set for 24 hours, tighten the nut using a hand wrench. Ensure bearing plates with headed studs are in intimate contact with the construction facing and the studs are located within the tolerances shown in the Construction Plans or specified herein.
		5. Weather Limitations Protect the shotcrete if it must be placed when the ambient temperature is below 40oF and falling or when it is likely to be subjected to freezing temperatures before gaining sufficient strength. Maintain cold weather protection until the in-place compressive strength of the shotcrete is greater than 725 psi. Cold weather protection includes blankets, heating under tents, or other means acceptable to the Engineer. Deposit the shotcrete mix at a temperature of not less than 50oF or more than 90oF.

Suspend shotcrete application during high winds and heavy rains unless suitable protective covers, enclosures or wind breaks are installed. Remove and replace newly placed shotcrete exposed to rain that washes out cement or otherwise makes the shotcrete unacceptable. Provide a polyethylene film or equivalent to protect the work from exposure to adverse weather.

* + 1. Curing Curing is not required for temporary construction facings to be covered by a CIP facing or whose service life is less than 36 months.
		2. Construction Facing Tolerances

|  |
| --- |
| **Construction Tolerances for Temporary Shotcrete Construction Facing** |
| Horizontal Location of Wire Mesh; Rebar; Headed Studs on Bearing Plates, from Plan location | +/- 0.6 inch |
| Headed studs location on bearing plate, from plan location | 0.25 inch |
| Spacing between reinforcing bars, from plan dimension | 1 inch |
| Reinforcing lap, from specified dimension | 1 inch |
| Thickness of shotcrete | 0.4 inch |
| Nail head bearing plate, deviation from parallel to wall face | 10 degrees |

* + 1. Safety Requirements Equip nozzlemen and helpers with gloves, eye protection, and adequate protective clothing during the application of shotcrete. The Contractor is responsible for meeting all federal, state, and local safety code requirements.
	1. Backfilling Behind Wall Facing Upper Cantilever If possible, compact backfill within 3 ft. behind the wall facing upper cantilever using light mechanical tampers.
	2. CIP Concrete Form or PC Panel Connection to Shotcrete Facing When mechanical, grouted, or epoxied anchors embedded into the shotcrete facing are used to support a one-sided CIP face form or PC Panel, perform pullout testing of the embedded anchors in accordance with ASTM C900 and as modified herein. Perform pullout testing of installed anchors prior to attachment of the face form. Select test anchor locations to be representative of the full wall surface area to be covered.

For facing areas up to 5000 ft2, perform a minimum of three flexure/shear pullout tests with the anchor located approximately mid-span between two adjacent nail heads and with the nail heads or other reaction points located approximately one-half the nail spacing from the anchor. For facing areas in excess of 5000 ft2, perform one additional flexure/shear pullout test for each additional 2500 ft2 of face area. Test these anchors to 1.5 times their required design load (calculated as the design concrete fluid pressure times the anchor tributary area).

Perform local punching shear pullout testing on 2 percent of the installed anchors. Place the load reaction support no closer to the edge of the anchor than the embedment depth of the anchor into the construction facing. Test these anchors to 2.0 times their required design load.

Modify the anchor and/or face form support system if the tested anchors do not meet the above test acceptance criteria. Modified anchor installation will require re-testing in accordance with the above testing criteria. Cost of anchor pullout testing is incidental to the work.

* 1. Wall Alignment and Permanent Facing Ensure that the wall is compatible with the horizontal and vertical alignment indicated in the Contract Plans. Survey control is the front face of the wall. Construct the exposed face of the wall to be straight and smooth with no discontinuities. Protrusions beyond the face of the walls are not allowed. Completely fill any voids between the temporary and permanent facing with shotcrete or grout. Provide architectural treatment for concrete facing if shown in the Contract Plans.
	2. Site Drainage Control Provide positive control and discharge of all surface water that will affect construction of the soil nail retaining wall. Maintain all pipes or conduits used to control surface water during construction. Repair damage caused by surface water at no additional cost. Upon substantial completion of the wall, remove surface water control pipes or conduits from the site. Alternatively, with the approval of the Engineer, pipes or conduits that are left in place, may be fully grouted and abandoned or left in a way that protects the structure and all adjacent facilities from migration of fines through the pipe or conduit and potential ground loss.

If water is used in the drilling operation, dispose of the water in such a manner that erosion in the vicinity of the wall is minimized. The Contractor is cautioned against the indiscriminate use of water that could create unstable slopes above and/or below the wall. Immediately repair any damage to the site by water or erosion at no cost to the Department.

# SOIL NAIL TESTING AND ACCEPTANCE REQUIREMENTS

* 1. General Perform both verification and proof testing on designated test nails and record required nail test data. Perform nail testing after the nail grout and shotcrete facing have cured for at least 72 hours and attained at least their specified 3-day compressive strength. Perform testing in less than 72 hours only if compressive strength test results, for tests performed verifies that the nail grout and shotcrete mixes being used will provide the specified 3-day compressive strengths in less time.

Specified test nail locations and/or testing frequencies are provided in an Appendix to this Special Note.

Test each production nail designated for testing within 21 calendar days of installation and provide a written summary of the test results to the Engineer within 7 calendar days after each test; include the following:

* + 1. bonded and unbonded lengths
		2. jacking length
		3. bar size and area

# Failure to begin testing within the specified time and/or failure to meet the submittal deadlines for nail test results may result in the Engineer suspending soil nail installation.

The Department will not make separate payment for the testing required in this section. All testing required in this section is included in the price of the wall(s).

* 1. Testing Equipment Testing equipment includes 2 dial gauges, dial gauge support, jack and pressure gauge, electronic load cell, and a reaction frame. The load cell is required only for the creep test portion of the verification test. Provide a description of test setup and jack, pressure gauge and load cell calibration curves in accordance with the submittals section of this Special Note.

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

Apply and measure the test load with a hydraulic jack and pressure gauge. Use a pressure gauge graduated in 75 psi increments or less. Use a jack and pressure gauge with a pressure range not exceeding twice the anticipated maximum test pressure. Use a jack with a ram travel no less than 125% of the anticipated maximum movement and sufficient travel to allow the test to be done without resetting the equipment. Monitor the nail load during verification tests with both the pressure gauge and the load cell. Use the load cell to maintain constant load hold during the creep test load hold increment of the verification test.

Measure the nail head movement with a minimum of 2 dial gauges capable of measuring to 0.001 inch. Use a dial gauge with a travel no less than 125% of the anticipated maximum movement and travel sufficient to allow the test to be done without having to reset the gauge. Visually align the gauge to be parallel with the axis of the nail and support the gauge independently from the jack, wall or reaction frame. Use two dial gauges when the test setup requires reaction against a soil cut face.

* 1. Verification Testing of Sacrificial Test Nails Perform verification testing of sacrificial test nails to verify the installation methods and design nail pullout resistance. Sacrificial test nails will not be incorporated as production nails. Perform verification tests to failure, or no less than 3.0 times the allowable pullout resistance. Bare bars can be used for the sacrificial verification test nails.

Develop and submit the details of the verification testing arrangement including the method of distributing test load pressures to the excavation surface (reaction frame), test nail bar size, grouted drillhole diameter and reaction frame dimensioning to the Engineer for approval in accordance with the Construction Submittals section. Construct verification test nails using the same equipment, installation methods, nail inclination, and drillhole diameter as planned for the production nails. Changes in the drilling or installation method may require additional verification testing as determined by the Engineer at no additional cost to the Department.

Use test nails with both bonded and temporary unbonded lengths. Prior to testing, grout only the bonded length of the test nail. Use a temporary unbonded length of at least 3 ft. Determine the bonded length of the test nail based on the production nail bar grade and size such that the allowable bar structural load is not exceeded during testing; use a bonded length not less than 10 ft. The maximum allowable bar structural load during testing is 90% of the yield strength for Grade 60 and Grade 75 bars, or 80% of the ultimate strength for Grade 150 bars. Provide larger verification test bar sizes, if required to safely accommodate the 10 ft. minimum test bond length and test to failure, at no additional cost to the Department.

Use the following equation for determining the verification test nail maximum bonded length to be used to avoid structurally overstressing the verification test nail bar size:

LBV = (C fY AS) / (3 Qd ), or 10 ft., whichever is greater.

LBV = Maximum Verification Test Nail Bonded Length (ft.)

C = 0.9 for Grade 60 and 75 bars and 0.8 for Grade 150 bars

fY = Bar Yield or Ultimate Stress (ksi)

(fY = 60, 75, and 150 ksi, respectively, for Grade 60, 75 and 150 bars)

AS = Bar Steel Area (in2)

3 = Factor of Safety against tensile failure during a Verification Test

Qd = Allowable pullout resistance (kips/ft., kips per linear foot of grouted nail lengths specified in the Construction Plans)

Determine the Design Test Load (DTL) during verification testing by the following equation:

DTL = Design Test Load (kips) = LBV x Qd

LBV = As-built bonded test length (ft.)

Qd = Allowable pullout resistance (kips/ft., kips per linear foot of grouted nail length specified in the Construction Plans)

MTL = 3.0 x DTL = Maximum Test Load (kips)

Incrementally load verification test nails to failure or a maximum test load of 300 percent of the Design Test Load (DTL) in accordance with the following loading schedule. Record the soil nail movements at each load increment.

|  |
| --- |
| **Verification Test of Sacrificial Nails Loading Schedule** |
| **Step** | **Load** | **Hold Time** |
| 1 | AL (0.05 DTL max.) | 1 minute |
| 2 | 0.25 DTL | 10 minutes |
| 3 | 0.50 DTL | 10 minutes |
| 4 | 0.75 DTL | 10 minutes |
| 5 | 1.00 DTL (Creep Test) | 30 minutes |
| 6 | 1.25 DTL (Creep Test) | 60 minutes |
| 7 | 1.50 DTL (Creep Test) | 300 minutes |
| 8 | 1.75 DTL | 10 minutes |
| 9 | 2.00 DTL | 10 minutes |
| 10 | 2.50 DTL or Failure | 10 minutes max. |
| 11 | 3.00 DTL or Failure | 10 minutes max. |
| 12 | AL (0.05 DTL max.) | 1 minute (record permanent set) |
| AL – Alignment Load, DTL – Design Test Load |

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

Hold each load increment for at least 10 minutes. Monitor the verification test nail for creep at the 1.00 DTL, 1.25 DTL, and 1.50 DTL load increments. Measure and record nail movements during the creep portion of the test (as applicable) at 1 minute, 2, 3, 5, 6, 10, 15, 20, 25, 30, 45, 60, 75, 90, 100, 150, 180, 210, 240, 270, and 300 minutes. Maintain the load during the creep test within 2 percent of the intended load by use of the load cell.

* 1. Verification Testing of Production Nails Perform verification testing of production nails using the same procedures as for verification testing of sacrificial nails with the following exceptions:
		1. The specified corrosion protection is required (bare bars are not allowed).
		2. The Maximum Test Load is 2.00 DTL.
		3. Creep testing is required only at a load of 1.50 DTL and the creep portion of the test is 60 minutes.

|  |
| --- |
| **Verification Test of Production Nails Loading Schedule** |
| **Step** | **Load** | **Hold Time** |
| 1 | AL (0.05 DTL max.) | 1 minute |
| 2 | 0.25 DTL | 10 minutes |
| 3 | 0.50 DTL | 10 minutes |
| 4 | 0.75 DTL | 10 minutes |
| 5 | 1.00 DTL | 10 minutes |
| 6 | 1.25 DTL | 10 minutes |
| 7 | 1.50 DTL (Creep Test) | 60 minutes |
| 8 | 1.75 DTL | 10 minutes |
| 9 | 2.00 DTL | 10 minutes |
| 10 | AL (0.05 DTL max.) | 1 minute (record permanent set) |
| AL – Alignment Load, DTL – Design Test Load |

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

* 1. Proof Testing of Production Nails Provide temporary unbonded lengths for each test nail. Isolate the test nail bar from the shotcrete facing and/or the reaction frame used during testing. Isolation of a test nail through the shotcrete facing will not affect the location of the reinforcing steel under the bearing plate. Submit the proposed test nail isolation methods, methods for providing an unbonded test length and methods for grouting the unbonded length subsequent to testing to the Engineer in accordance with the Construction Submittals section. Where temporary casing of the unbonded length of test nails is provided, install the casing in a way that prevents any reaction between the casing and the grouted bond length of the nail and/or the stressing apparatus.

Use production proof test nails with both bonded and temporary unbonded lengths. Prior to testing grout only the bonded length of the test nail. The minimum temporary unbonded length of the test nail is 3 ft. Determine the bonded length of the test nail based on the production nail bar grade and size such that the allowable bar structural load is not exceeded during testing. The maximum allowable bar structural load during testing is 90 percent of the yield strength for Grade 60 and Grade 75 bars, or 80 percent of the ultimate strength for Grade 150 bars.

Use the following equation for sizing the proof test nail bonded length to avoid overstressing the production nail bar size:

LBP = (C fY AS) / (1.5 Qd ), or 10 ft., whichever is greater. \*

LBP = Maximum Proof Test Nail Bonded Length (ft.)

C = 0.9 for Grade 60 and 75 bars and 0.8 for Grade 150 bars

fY = Bar Yield or Ultimate Stress (ksi)

(fY = 60, 75, and 150 ksi, respectively, for Grade 60, 75 and 150 bars)

AS = Bar Steel Area (in2)

1.5 = Factor of Safety against tensile failure during a Proof Test

Qd = Allowable pullout resistance (kips/ft., kips per linear foot of grouted nail length specified in the Construction Plans)

* + - Production proof test nails shorter than 12 ft. in length may be constructed with less than the minimum 10 ft. bond length; however the unbonded length is limited to 3 ft.

Determine the Design Test Load (DTL) during verification testing by the following equation:

DTL = Design Test Load (kips) = LBP x Qd

LBP = As-built bonded test length (ft.)

Qd = Allowable pullout resistance (kips/ft., kips per linear foot of grouted nail length specified in the Construction Plans)

MTL = 1.5 x DTL = Maximum Test Load (kips)

Perform proof tests by incrementally loading the proof test nail to a maximum test load of 150 percent of the Design Test Load (DTL). Measure and record the nail movement at each load in the same manner as for verification tests. Monitor the test load by a jack pressure gauge with a sensitivity and range meeting the requirements of pressure gauges used for verification test nails. At load increments other than maximum test load, hold the load long enough to obtain a stable reading. Apply incrementally loads in accordance with the following loading schedule. Record the soil nail movements at each load increment.

|  |
| --- |
| **Proof Test Loading Schedule** |
| **Step** | **Load** | **Hold Time** |
| 1 | AL (0.05 DTL max.) | Until Stable |
| 2 | 0.25 DTL | Until Stable |
| 3 | 0.50 DTL | Until Stable |
| 4 | 0.75 DTL | Until Stable |
| 5 | 1.00 DTL | Until Stable |
| 6 | 1.25 DTL | Until Stable |
| 7 | 1.50 DTL (Max Test Load) | Creep Test (See Below) |
| AL – Alignment Load, DTL – Design Test Load |

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

Start the creep tests as soon as the maximum test load (1.50 DTL) is applied. Depending on performance, perform either 10 minute or 60 minute creep tests at the maximum test load (1.50 DTL). Start the creep period as soon as the maximum test load is applied and measure and record the nail movement at 1 minute, 2, 3, 5, 6, and 10 minutes. Where the nail movement between 1 minute and 10 minutes exceeds 0.04 inches, maintain the maximum test load an additional 50 minutes and record movements at 20 minutes, 30, 50, and 60 minutes. Maintain all load increments within 5 percent of the intended load.

* 1. Test Nail Acceptance Criteria A test nail is considered acceptable when all of the following criteria are met:
		1. For verification tests on sacrificial nails, a total creep movement of less than

0.08 inches per log cycle of time over the final log cycle of time of each load increment (between 3 and 30 minutes for 1.00 DTL, 6 and 60 minutes for

1.25 DTL, 30 and 300 minutes for 1.50 DTL) and the creep rate is linear or decreasing throughout the creep test load hold period.

1. For verification tests on production nails, a total creep movement of less than 0.08 inches between the 6 and 60 minute readings is measured during creep testing and the creep rate is linear or decreasing throughout the creep test load hold period.
2. For proof tests, a total creep movement of less than 0.04 inches is measured between the 1 and 10 minute readings, or a total creep movement of less than 0.08 inches is measured between the 6 and 60 minute readings and the creep rate is linear or decreasing throughout the creep test load hold period.
3. For verification tests, the total measured movement at 2.0 x DTL exceeds 80% of the theoretical elastic elongation of the test nail unbonded length.
4. For proof tests, the total measured movement at 1.5 x DTL exceeds 80% of the theoretical elastic elongation of the test nail unbonded length.
5. A pullout failure does not occur prior to or at 2.0 x DTL during verification testing of sacrificial or production nails or 1.5 x DTL during proof testing.

Pullout failure is defined as the load at which attempts to further increase the test load simply result in continued pullout movement of the test nail. Record the pullout failure load as part of the test data.

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

* 1. Test Nail Rejection If a test nail does not satisfy the acceptance criterion, the Engineer will implement the procedures below.
		1. For Verification Tests on Sacrificial Nails, the Engineer will evaluate the results of each verification test and will reject installation methods that do not satisfy the nail testing requirements. Propose alternative methods and install replacement verification test nails. Install and test replacement test nails at no additional cost to the Department and with no extension of contract time. The Engineer may require the Contractor to replace some or all of any production nails installed prior to acceptance of Sacrificial Nails; alternatively, the Engineer may require additional verification or proof tests on these production nails.
		2. For Verification or Proof Tests on Production Nails, the Engineer may require the Contractor to replace some or all of the installed production nails between a failed test nail and the adjacent passing test nail. Alternatively, the Engineer may require the installation and testing of additional test nails to verify that adjacent previously installed production nails have sufficient load carrying capacity. Contractor modifications may include, but are not limited to: the installation of additional test nails; increasing the drillhole diameter to provide increased capacity; modifying the installation or grouting methods; reducing the production nail spacing from that shown on the Construction Plans and installing more production nails at a reduced capacity; or installing longer production nails if sufficient right-of way is available and the pullout capacity behind the failure surface controls the allowable nail design capacity. The nails may not be lengthened beyond the right-of-way or easement. Installation and testing of additional test nails or installation of additional or modified nails as a result of test nail failure(s) will be at no additional cost to the Department.

# 10.0 RECORDS

Provide the Engineer with the following final records:

1. As-built drawings showing:
	1. The actual location and orientation of the soil nails, including deviation from specified tolerances.
	2. Nail capacity, nail type, installed drillhole and bar diameter, designed and installed nail length.
	3. The type of testing performed for each soil nail and test results.
	4. The locations of any instrumentation installed and any required instrumentation records.
	5. Finished ground line elevations behind the wall and finished grade elevations in front of the wall.
2. Other records as required by Section 106 of the Standard Specifications.
3. Structural Steel records required by Section 607 of the Standard Specifications.
4. Record plans conforming to Section 105.03 of the Standard Specifications.
5. Construction Records including:
	1. Contractor's name
	2. Drill rig operator's name
	3. Date and time of start and finish of drilling
	4. Drilling difficulties
	5. Caving or sloughing of excavation or drillhole
	6. Groundwater conditions
	7. Drill casing requirements
	8. Grouting records including:
* Date, time, and method grout was placed cement type
* Volume of grout placed grout pressure

# MEASUREMENT AND PAYMENT

* 1. The Department will pay for the accepted quantities of "Soil Nail Wall" under the following:

**Code Pay Item Pay Unit**

20603ED SOIL NAIL WALL SQFT

The contract unit price per Square Foot will constitute full compensation for all costs including materials, labor, tools, equipment, and other incidental items required for designing, constructing, and performing nail testing for the permanent soil nail wall(s) as described herein. This may include but is not limited to the following items: installing sacrificial and production soil nails, providing corrosion protection, shotcrete, concrete facing (if required), wall drainage, toe drainage, surface drainage, anchorage hardware, verification tests, proof tests, all required submittals and records, and other incidental items necessary to provide a complete permanent soil nail wall. Earth moving, backfilling, drainage, any temporary shoring due to phased construction, and any other earthwork necessary to complete these walls and not included in other bid items, is included as an incidental part of this work.

* 1. All measurement will be based on plan dimensions or dimensions as ordered in writing. Additional areas of wall required due to unforeseen foundation conditions or other reasons and approved in writing by the Engineer will be paid at the contract unit price. In the event a decrease in the area of a wall is required, subject to acceptance by the Department, payment will be reduced due to the decrease in the wall area or length.