SPECIAL PROVISIONS
FOR
SOIL NAIL WALL SYSTEM

Linn County

Project Number
STP-A-1187(771)--86-57

Effective Date
January 20, 2016

THE STANDARD SPECIFICATIONS, SERIES 2015, ARE AMENDED BY THE FOLLOWING MODIFICATIONS AND ADDITIONS. THESE ARE SPECIAL PROVISIONS AND THEY SHALL PREVAIL OVER THOSE PUBLISHED IN THE STANDARD SPECIFICATIONS.

DESCRIPTION

This work shall consist of furnishing the nails, corrosion protection details, materials, field tests and the construction of a retaining wall by internally reinforcing the soil mass with grouted reinforcing elements (nails) in close conformity with the lines, grades, dimensions and design parameters on the plans or as established by the Engineer.

The wall shall be constructed from the top down as the soil in front of the wall is removed and the nails are installed and grouted at each level. The exposed soil face shall be protected with a mesh reinforced shotcrete facing. Drainage systems when required shall be installed prior to applying shotcrete. When shown on the plans, a structural cast-in-place or precast concrete facing may subsequently be constructed and suitably attached.

1-1 GENERAL

The Contractor shall select the nail installation method and may increase the drill hole diameter or length to develop the required design loads shown on the plans.

2-1 MATERIALS

A. Steel Nails: AASHTO M-31. Thread as necessary. Only nails greater than 38 feet in length may be spliced using a mechanical splicer.

B. Corrosion Protection: Where required, corrosion protection shall consist of one of the following as specified on the Plans:

1. Epoxy Coating: The minimum thickness of coating applied electrostatically to the nail shall be 14 mils and the maximum 18 mils. The epoxy coating shall be in accordance with AASHTO M-284. Bend test requirements shall be waived.

2. Encapsulation: The encapsulation shall be fabricated from high density corrugated polyethylene (PE) tubing conforming to the requirements of AASHTO M-252 with a minimum wall thickness of 30 mils or deformed steel tubing or pipe with a minimum wall thickness of 25 mils. The annulus between the nail and the encapsulating tube shall be a minimum of 0.5 inches and be grouted with grout conforming to Section C (7) of this specification.

C. Steel Welded Wire Fabric: AASHTO M-55

D. Cast-in-Place or Precast Concrete: Provide Class A concrete for structural concrete facing where required and shown on the plans, conforming to the requirements of Section 2403, of the Standard Specifications.

E. Permanent Structural Shotcrete Facing:

1. Materials:

Cement - AASHTO M-85, Type I, II, or III
Fine Aggregate - AASHTO-M-6
Coarse Aggregate - AASHTO-M-80, Class B for quality
- AASHTO-M-43, Size 7, 8 or 67
Fly Ash - AASHTO-M-295
Silica Fume - No current standard
Air Entraining Admixtures for Wet Mix - AASHTO M-194
Plasticizers - AASHTO M-194, Type A, D, F, G

Accelerating additives shall be compatible with the cement used, be non-corrosive to steel and shall not promote other detrimental effects such as cracking and excessive shrinkage, and shall not contain calcium chloride. They are to be used in accordance with manufacturer's recommendations. Silica fume, if used, shall not exceed 10% of the cement weight and shall be an admixture with a minimum of 90% SiO_2 with a proven record of performance for use in shotcrete.

Water used in the shotcrete mix shall be potable, clean and free from substances which may be injurious to concrete and steel. The water shall also be free of elements which would cause staining.

Premixed and prepacked concrete product specifically manufactured as a shotcrete product may be provided for on-site mixed shotcrete if approved by the engineer. The packages shall contain cement and aggregates conforming to the material portion of this specifications.

2. Shotcrete Quality: Shall be produced by wet mix process achieving a minimum compressive strength of 2600 psi in 7 days and 4000 psi in 28 days.

   Shotcrete will be accepted based on 28 day strength. The contractor may submit a proposal for expediting the work. The contractor's proposal shall detail methods to ensure that the minimum required 28 day strength is attained.

3. Mixture Proportions: Submit for acceptance the recommended mix proportion, strength results, water-cement ratio and source of materials. Select mix proportion on the basis of compressive strength tests of specimens continuously moist cured until tested at 28 days in accordance with AASHTO T-22. For mixture acceptance purposes, average core compressive strength must be equal to 1.2 times the required compressive strength specified in (2) above. Maximum water cement ratio shall be 0.40, air content 6.5%, ±1.5% and slump 1.5 to 3 inches.

4. Batching and Mixing: Aggregate and cement may be batched by weight or by volume. Provide mixing equipment capable of thoroughly mixing the materials in sufficient quantity to maintain placing continuity. Provide ready mix shotcrete complying with AASHTO M-157.

5. Delivery Equipment: Provide equipment capable of delivering the premixed material accurately, uniformly, and continuously through the delivery hose. Follow recommendations of the equipment manufacturer on the type and size of nozzle to be used, and on cleaning, inspection and maintenance of the equipment. Ready mixed shotcrete may be delivered in transit mixers which comply with AASHTO M-157.

   Provide a supply of clean, dry air adequate for maintaining sufficient nozzle velocity for all parts of the work and if required, for simultaneous operation of a suitable blow pipe for clearing away rebound. The compressor shall be capable of providing a minimum of 315 cfm per operating nozzle.

6. Pre-Construction Testing: Test panels shall be made by each application crew using the equipment, materials, mixture proportions and procedures proposed for the job prior to the commencement of the work.

   A test panel at least 30 inch by 30 inch shall be made for each mixture being considered and for each shooting position to be encountered in the job. The test panels shall be fabricated to the same thickness as in the structure, but

not less than 4 inches. Take at least five 3 inch diameter cores from each panel for testing in accordance with AASHTO T-24.

Samples for testing shall be obtained be the Contractor in the presence of the Engineer, and tested by the Engineer.

7. Safety requirements: Special attention shall be given to eye and dust protection hazards when shotcrete is to be applied. Cement and other admixtures are caustic and may cause skin and respiratory irritation unless safety measures are taken in addition to required ventilation. During the application of shotcrete, provide nozzle operator and helpers with gloves, face shields, and adequate protective clothing.

8. Finish: Provide undisturbed gun finish of shotcrete as applied from nozzle without hand finishing unless otherwise specified. Clean area at base of each lift to insure good joints between lifts.

9. Curing: Immediately after completion, keep shotcrete continuously moist for at least 24 hours. Use one of the following materials or methods.

    a. Continuous sprinkling.

    b. Absorptive mat or fabric, sand, or other covering kept continuously wet.

    c. Curing compounds. In accordance with AASHTO-M-148, Type ID or Type 2. On natural gun or flash finishes, use the application rate of 1 gallon per 100 cubic feet. Do not use curing compounds on any surfaces against which additional shotcrete or other cementitious finishing materials are to be bonded unless positive measures such as sandblasting are taken to completely remove curing compounds prior to the application of such additional materials.

        Provide additional final curing immediately following the initial curing and before the shotcrete has dried. Use one of the following materials or methods:

        (i) Continue the method used in initial curing.
        (ii) Application of impervious sheet material conforming to AASHTO M-171.

        Continue curing for the first 7 days after shotcreting or until the required 7 day strength is obtained. During the curing period, maintain shotcrete above 38° F and in a moist condition as specified.

10. Construction Testing: Cut cores from the structure and test in accordance with AASHTO T-24. A minimum of three cores shall be taken from each 1000 cubic feet of completed facing.

    Alternately, make one test panel with minimum dimensions of 18 inches by 18 inches by 4 inches gunned in the same position as the work represented for each 1000 cubic feet of competed facing. Panels shall be gunned during

the course of the work by the Contractor's regular nozzle operator. Field sure panels in the same manner as the work, except that the test specimens shall be soaked in water for a minimum of 40 hours prior to testing. The Contractor shall cut a minimum of three cores from each panel for testing in accordance with AASHTO T-24.

The average compressive strength of each set of three cores must equal or exceed 85 percent of the compressive strength specified in E.2 of these specifications.

F. Temporary Shotcrete Facing: The Contractor shall submit for approval by the Engineer, materials, methods and control procedures for this work.

G. Grout for Nails: Provide a neat cement or a sand cement grout to be used in soil nail anchorage consisting of a pumpable mixture capable of reaching a cube strength of 3000 psi in accordance with AASHTO T-106. Chemical additives which control, bleed or retard set in the grout are to be used only when approved in writing by the Engineer. Expansive additives shall not be used.

H. Fasteners and Attachment Devices: Provide high strength nuts conforming to AASHTO M-291, Grade B, Hexagonal, or equivalent. Provide plates conforming to AASHTO M-183 or equivalent. Provide only plastic centralizers of a minimum diameter 1 inch smaller than the nominal diameter of the drill hole which permit free flow of grout. Centralizers must be provided inside and outside of encapsulated nail assemblies and shall be spaced no further than 10 feet apart.

I. Horizontal Drains: Provide as required and shown on the plans, slotted and unslotted PVC pipe conforming to AASHTO M-278. The Contractor shall make provisions to assure that the hole does not collapse prior to the insertion of the slotted drain. Only the front 12 inches of drain pipe shall be unslotted.

J. Vertical Wall Drains: Provide as required and at drain outlet locations shown on the plans, prefabricated, fully wrapped geocomposite drains. The core, not less than 0.25 inches or more than 0.50 inches thick, shall be either a preformed grid or embossed plastic or a system of plastic pillars and interconnections forming a semi-rigid mat. The core material when covered with filter fabric shall be capable of maintaining a drainage void for the entire height of permeable liner. Preformed drains shall be no wider than 12 inches unless special methods are used to ensure adherence of the shotcrete to the fabric and to preclude the fabric from sagging under the weight of the shotcrete. They shall be suitably outletted or connected to a longitudinal drain at the bottom of the structure When splicing of drains is required, full flow through the splice shall be maintained and splices shall be suitably protected from damage and contamination during subsequent shotcreting. The shotcrete shall be of full thickness over the drain.

3-1 CONSTRUCTION REQUIREMENTS

A. The construction sequence shall be as specified herein, unless otherwise approved by Engineer. No excavations steeper than those specified shall be made below the soil nail wall without written approval of Engineer.

B. Submittals: Provide shop drawings, details, test nail procedures, material and mill test certificates, mix designs, qualifications, construction procedures and detailed construction sequencing plans including excavation sequences, 45 calendar days prior to the commencement of the work. The Engineer shall approve or reject the Contractor's Working Drawings and design submission within thirty working days after receipt of the submission.

Submit for approval calibration data for each test jack, pressure gauge and master pressure gauge used.

Calibration tests shall be performed by an independent testing laboratory within 60 calendar days of the date submitted. Approval or rejection of the calibration data shall be given within 5 working days of submittal.

C. Qualifications: Submit proof of four projects similar in size and scope on which Contractor has designed and/or installed permanent soil nails or ground anchors in the past 2 years. The Contractor's staff on this project shall include a supervising Engineer with at least 3 years of experience in the construction of permanent nailed or ground anchor walls.

Drilling operators and foreman shall have a minimum of 2 years of experience installing soil nails or permanent ground anchors with the Contractor's organization. Submit documentation showing that project personnel have appropriate qualifications. Inadequate proof of personnel qualifications shall be cause for withholding construction approval. Changes to previously approved personnel must be approved by the Contracting Authority in writing.

Provide shotcreting nozzle operators with at least 1 year experience in the application of shotcrete on projects of comparable nature or work under the immediate supervision of a foreman or instructor with at least 2 years of such experience.

The Engineer shall approve the Contractor's qualification and staff within 15 working days after the receipt of the submission. Work shall not be started nor any materials ordered until the Contractor's qualifications are approved. The Engineer may suspend the work if the Contractor substitutes unqualified personnel for approved personnel during construction. If work is suspended due to the substitution of unqualified personnel, the Contractor shall be fully liable for additional costs resulting from the suspension of the work and no adjustments in contract time resulting from the suspension will be allowed.

3-2 EXCAVATION

A. With reference to the terms and conditions of the construction standards for excavations set forth in the OSHA "Safety and Health Regulations for Construction", Chapter XVII of Title 29, CFR, Part 1926, the Contractor shall employ a competent person when necessary.

B. During initial mass grading, the Contractor shall not excavate to the wall face but shall maintain a working berm of native material in front of the wall. The working berm shall extend out from the wall a minimum distance of 10 feet, and shall be cut

down from that point at a slope determined to be safe by the Contractor but not steeper than a 1:1 ratio unless otherwise approved by Engineer. Over-excavating the original ground beyond the wall face shall not be allowed.

C. Where determined by Engineer and Contractor to be necessary to maintain local stability or reduce shotcrete quantities, a stabilizing berm shall be used as shown in the contract documents. The stabilizing berm shall extend horizontally from, the bottom of the shortcrete a minimum distance of 1 foot and shall be cut down from that point at a slope determined to be safe by the Contractor but not steeper than 0.5:1 ratio unless otherwise approved by Engineer.

D. Excavation of the soil face to final grade and application of the shotcrete shall be done in the same work shift unless otherwise approved by Engineer. Extensions of the excavation face exposure period shall be submitted and verified by the Contractor. The Contractor shall demonstrate for each material type that the unsupported vertical cut will be stable over the proposed exposure period. Risk of damage to existing structures or structures included in the work shall be borne by the Contractor where approval for extended face exposure period is granted by Engineer. Where extension of the face exposure period is allowed, the Contractor shall provide and install polyethylene sheets properly anchored to the top and bottom of the excavation to reduce degradation of the cut face caused by changes in soil moisture.

E. The Contractor shall ensure that installed nails are not damaged during excavation of the stabilizing berm. Nails damaged or disturbed during excavation of the stabilizing berm shall be repaired or replaced by the Contractor to the satisfaction of the Engineer. Excavation of the stabilizing berm shall not begin within 24 hours of nail grouting unless the nail grout is determined to be in a fluid state.

F. Excavations shall not be advanced until nail installation, reinforced shotcrete placement, and nail testing for the preceding lifts are complete and acceptable to Engineer. Prior to advancing the excavation, shotcrete and nail grout on the preceding lift shall have reached 25% and 50% of the 7-day strength, respectively. The meaning of “advancing the excavation” shall include removal of the stabilizing berm below the shotcrete. Exposed native materials shall not have an unsupported cut height greater than the vertical nail spacing plus the reinforcing lap required to properly develop shotcrete reinforcement unless otherwise approved by Engineer.

G. Construction sequences other than those described herein shall be considered provided that submittal requirements as described herein are satisfied.

H. Cobbles and boulders may be encountered at the soil face during excavation. Contractor shall remove all cobbles and boulders that protrude from the soil face more than two inches into the design shotcrete thickness shown on the plans and shall fill the voids with shotcrete. Any shotcrete used to fill voids created by the removal of cobbles and boulders or other obstructions shall be considered incidental to shotcrete wall facing and no additional payment above the bid price shall be made.

I. Facial raveling at the face or local instability of the exposed cut due to the presence of perched groundwater, problematic soil conditions, equipment vibration or other

causes shall be brought to the immediate attention of Engineer. Work shall be suspended in these areas until remedial measures are submitted and approved by Engineer and have successfully arrested facial instability. Remedial measures may include lagging, false forming, flash coat application of steel fiber reinforced shotcrete, installation of horizontal PVC drains or a reduction in the width and/or height of the exposed excavation face.

3-3 NAIL INSTALLATION

A. No classification of excavated materials from nail holes will be made except for identification purposes. Nail installation shall include the removal and subsequent handling of all materials encountered in excavating the nails to the depths required.

B. Drilling equipment shall be designed to drill straight and clean holes. The size and capability of drilling equipment shall be suitable for installation of nails as specified herein.

C. Each nail hole shall be excavated at the locations and to the minimum lengths indicated on the plans unless otherwise approved by Engineer. Cuttings shall be removed using highly compressed air as used during the test nail program. The nail hole shall be considered clean upon retraction of the drill string unless hole has caved or another defect is observed. The nail hole shall then be wetted such that the entire side walls are moistened and the excess water removed from the hole using highly compressed air. Over-cleaning shall be avoided. No portion of the nail hole shall be left open for more than 60 minutes prior to grouting unless otherwise approved by Engineer.

D. The Contractor shall provide positive support as the drilling proceeds as required to prevent sloughing and caving of the hole caused by excessive groundwater infiltration prior to grouting. Where caving and sloughing occurs, holes shall be continuously supported and drilled without the loss of ground through casing or auger-cast installation methods. Drilling fluids such as bentonite or water shall be allowed as a means of hole support. All additional installation, material, and other costs due to casing holes shall be borne by the Contractor.

E. Casing shall be of steel or fiber construction and shall be of ample strength to withstand handling and installation stresses, grout pressure, and surrounding earth and groundwater pressures. Casings shall be removed as the grout is placed. The casing extraction shall be facilitated by the use of a vibratory extractor, if required. During removal, the casing shall be continually aligned with the hold, and the grout surface within the casing shall be continually observed for maintenance of “head” sufficient to offset the external groundwater/soil pressure. Casing seals shall not be broken until the level of grout within the casing provides adequate head to prevent unstable soil or groundwater from containing or diluting the grout. The contractor shall maintain at least five feet of grout head above the bottom of the casing at all times to preclude “blowins”.

F. Where casing of the unbonded length of test nails is provided, casing shall be placed in a manner which precludes causing any reaction between the casing and the grouted zone of the nail and/or the stressing apparatus during testing.

3-4 PRODUCTION NAILS

A. No drilling or bar placement for production nails shall be allowed without prior written approval by Engineer of the proposed drilling, installation and grouting methods. Only installation methods which have been successfully verification-tested shall be approved for production nail installation. Methods which fail to meet the verification and proof test acceptance criteria shall be rejected. Methods which differ from those used during installation of verification nails shall require additional verification testing.

B. Nails shall be installed at the locations and to the minimum grouted lengths as shown on the plans or designated by Engineer. Mails may be added, eliminated, or relocated as determined by Engineer to accommodate actual field conditions.

C. The diameter of the hole, drilling method, grout composition and installation method shall be as shown on the Plans and employed during the test nail phase. The nail hole shall have a diameter as shown on the plans to accommodate the required tendon, couplers, and centralizers.

D. Bar Installation

1. Bar sizes and grades shall be provided for each nail hole as indicated on the test plans. The bar shall be fitted with centralizers as shown in the plans (at least two centralizers per bar) and inserted into the hole to the required depth without difficulty. Where the bar cannot be completely inserted, the Contractor shall remove the bar and clean or redrill the hole to permit unobstructed installation. Partially installed bars shall be rejected.

E. Grouting

1. After installation of the nail bar the nail hole shall be grouted. Gravity flow of grout into the nail hole from the excavation face shall not be allowed. The grout shall be injected at the lowest point of each drill hole through a grouting conduit and the hole filled in one continuous operation; no cold joint shall be allowed excluding proof test nails. The grout shall be pumped through grout tubes, casing, or drill rods. The conduit delivering the grout shall be maintained at least five feet below the surface of the grout as the conduit is withdrawn. The grouting conduit shall be withdrawn at a slow and even rate as the nail hole is filled in a manner which precludes the creation of voids. A sufficient quantity of grout to fill the entire nail hole shall be available in delivery trucks at the site when the first grout is placed in each nail.

F. If the quality of construction operation results in a nail of questionable or inferior integrity, the steel and grout shall be removed from the hole, disposed of and replaced with fresh grout and undamaged steel.

G. The quantity and pressure of the grout shall be carefully controlled. The grout equipment shall produce a uniformly mixed grout free of lumpy and undispersed cement. A positive displacement grout pump shall be provided. The grouting equipment shall be sized to enable the entire nail to be grouted in one continuous operation. The mixer shall be capable of continuously agitating the grout during placement.

3-5 TEST NAIL ISOLATION

A. Isolation of the test nails to be incorporated into the production nail schedule during shotcrete application shall be made in a manner which maintains the tolerances of bearing bars and walers below the bearing plate. Blockouts in the shotcrete that result in no reinforcing below the nail head shall not be allowed. A detail of the method of test nail isolation shall be submitted to Engineer for approval.

3-6 NAIL TESTING

A. Both verification and proof testing of the nails shall be required. The Contractor shall supply all material, equipment, and labor to perform the tests. The Engineer shall measure and record all required data in an acceptable manner. Testing or stressing of nails shall not be performed within 3 days of grouting nails or unless the strength of the grout has reached 50% of the 7 day strength. No testing or stressing of nails should be performed within 3 days if shotcrete application if the reaction frame bears on the wall unless the shotcrete has developed 50% of its 28 day strength.

3-7 TESTING EQUIPMENT

A. Testing equipment shall include two dial gauges, a dial gauge support, jack and pressure gauge, an electric load cell, master pressure gauge and a reaction frame.

B. A minimum of two dial gauges capable of measuring to 0.001 inch shall be available at the site to measure the ground anchor nail movement. The dial gauges shall have a minimum stroke equal to the theoretical elastic elongation of the total nail length plus 1 inch. The dial gauges shall be aligned within 5 degrees from the axis of the nail. A hydraulic jack and pump shall be used to apply the test load.

C. The jack and pressure gauge shall be calibrated by an independent testing laboratory as a unit. The pressure gauge shall be graduated in 100 psi increments or less and shall have a range not exceeding twice the anticipated maximum pressure during testing unless otherwise approved by Engineer. The pressure gauge shall be used to measure the applied load. The minimum ram travel of the jack shall not be less than the theoretical elastic elongation of the total nail length at the maximum test load plus 1 inch. The jack shall be capable of applying each load in less than 1 minute.

D. The jack shall be independently supported and centered over the nail so that the nail does not carry the weight of the jack. A calibrated master pressure gauge shall also be kept at the site. The master gauge shall be calibrated with the test jack and pressure gauge as a unit. The loads on the nails during the verification tests shall be monitored with both a pressure gauge and electric load cell. The Contractor shall provide recent calibration curves in accordance with submittals. The stressing equipment shall be placed over the nail in such a manner that the jack, bearing plates, load cell, and stressing anchorage are in alignment. The jack shall be positioned at the beginning of the test such that unloading and repositioning of the jack during the test will not be required.

E. The reaction frame shall be sufficiently rigid and of adequate dimension such that excessive deformation of the test apparatus requiring repositioning of any components shall be avoided. Where the reaction frame bears directly on the

shotcrete, the reaction frame shall be designed to preclude fracture of the shotcrete. No part of the reaction frame shall bear within 6 inches of the edge of the test nail blockout unless otherwise approved by Engineer,

3-8 VERIFICATION TESTING

A. Verification testing shall be performed during production nail installation to verify the installation methods, soil conditions, and nail capacity. The details of the verification testing arrangement including the method of distributing test load pressures to the excavation surface (reaction frame), nail bar size, grouted hold diameter and reaction plate dimensioning, shall be developed and submitted by the Contractor. All nail testing shall be made using the same equipment methods, and hole diameter as planned for the production nails. Changes in the drilling or installation method shall require additional verification testing as determined by Engineer. The nails used for the verification tests shall be sacrificial and shall not be incorporated into the production nail schedule.

B. At least two verification nails using a No.10 bar grade 75 or longer shall be installed. Successful verification tests are required prior to production nail installation. The locations of the verification tests shall be determined by the Contractor and approved by the Engineer.

C. Test nails shall have both bonded and unbonded portions. Prior to testing only the bonded length of the test nail shall be grouted. The Engineer shall determine the bonded and unbonded lengths of the test nail. The unbonded length of the test nail shall be at least 3 feet unless otherwise approved by Engineer. The bonded length shall be determined by Engineer based on the bar grade and size and installation method provided by the Contractor such that the allowable bar load is not exceeded. The bonded length shall not be less than indicated above. The allowable bar load during testing shall not be greater than 80% of the ultimate strength of the steel for 150 ksi bars nor greater than 90% of the yield strength for 60 and 75 ksi bars.

D. The maximum verification test bonded length Lbv shall not exceed the test allowable bar load divided by two times the design value, as shown in the following equation:

$$L_{BV} \leq \frac{CFyA_s}{2A_D}$$

Where: L_{BV} = Maximum Test Nail Bond Length (ft)
Fy = Bar Yield Stress (ksi)
A_s = Bar Area (square inches)
A_D = Design Adhesion (kips per foot) as shown on the plans
C = 0.8 for Grade 150 bar and 0.9 for Grade 60 and 75 bar

The design load during testing shall be determined by the following equation:

$DL = L_B \times A_D$

Where,

DL = Design Load

L_B = As-built bonded length (feet)
A_D = Design adhesion (specified herein as kips per foot)

E. Verification test nails shall be incrementally loaded to twice the design load and movements recorded by the Contractor in accordance with the following schedule:

AL 1 minute
0.25DL 10 minutes
0.50DL 10 minutes
0.75DL 10 minutes
1.00DL 10 minutes
1.25DL 10 minutes
1.50DL 60 minutes
1.75DL 10 minutes
2.00DL 10 minutes
Where AL = Alignment Load

F. Each load increment shall be held for at least 10 minutes. The verification test nail shall be monitored for creep at 1.50 DL load increment. Nail movements during the creep portion of the test shall be measured and recorded at 1 minute, 2, 3, 5, 6, 10, 20, 30, 50, and 60 minutes. Extended creep measurements may be required and shall be monitored as determined by Engineer. All load increments shall be maintained within 5% of the intended load by use of the load cell. The nail shall be unloaded increments of 25% with measurements of deflection at each increment.

G. Upon successful completion of the verification test, the nail shall be loaded in 25% increments until stable reading is obtained to no more than allowable bar load ($CFyA_s$) to determine the ultimate pullout activity.

3-9 PROOF TESTING

A. Proof testing shall be performed on at least 5% of the production nails in each shotcrete lift to verify the Contractor's methods and the design nail capacity. The locations and number of these tests shall be determined by the Contractor.

B. Proof tests shall have both bonded and unbonded portions. Prior to testing only the bonded length of the test nail shall be grouted. The Engineer shall determine the bonded and unbonded lengths of the test nail. The unbonded length of the test nail shall be at least 3 feet. The bonded length of the test nail shall be determined by Engineer such that the allowable bar load is not exceeded but shall not be less than 20 feet unless otherwise approved by Engineer. The allowable bar load shall not exceed 90% of the yield strength for 60 and 75 ksi bars nor greater than 80% of the ultimate strength of the steel for 50 ksi.

C. The maximum proof test bonded length L_{BP} shall not exceed the allowable bar load divided by 1.3 times the design adhesion value.

$$L_{BP} \leq \frac{CFyA_s}{1.3\ A_D}$$

Where: L_{BP} = Test Nail Bond Length (feet)
Fy = Bar Yield Stress (ksi)
A_s = Bar Stress Area (square inches)
A_D = Design Adhesion (kips per foot)
C = 0.8 for Grade 150 bar and 0.9 for Grade 60 and 75 bar

D. Proof tests shall be performed by incrementally loading the nail to 130% of the design load. The design load shall be determined as for verification test nails. The nail movement at each load shall be measured and recorded by the Engineer in the same manner as for verification tests. The load shall be monitored by a pressure gauge with sensitivity and range meeting the requirements of pressure gauges used for verification test nails. At load increments other than maximum test load, the load shall be held long enough to obtain a stable reading. Incremental loading for proof test shall be in accordance with the following schedule.

AL
0.25DL
0.50DL
0.75DL
1.00DL
1.30DL

AL = Nail Alignment Load
DL = Nail Design Load

E. All load increments shall be determined within 5% of the intended load. Depending on performance, either 10 minute or 60 minute creep tests shall be performed at the maximum test load. The creep period shall start as soon as the maximum test load is applied and the nail movement with respect to fixed a reference shall be measured and recorded at 1 minute, 2, 3, 5, 6, and 10 minutes. Where nail movement between 1 minute and 10 minutes exceeds 0.04 inch, the maximum test load shall be maintained an additional 50 minutes and movements shall be recorded at 20 minutes, 30, 50, and 60 minutes, nails which fail in creep shall be brought to the attention of Engineer.

3-10 TEST NAIL ACCEPTANCE

A. A test nail shall be considered acceptable when:

1. For verification tests, a creep rate less than 0.08 inch per log cycle of time is observed during creep testing and the rate is linear or decreasing throughout the load hold.

2. For proof tests where less than 0.04 inches of movement is observed between the 1 minute and 10 minute interval during the 10 minute creep test or a creep rate less than 0.08 inches per log cycle of time is observed during the 60 minute creep test and the creep rate is linear or decreasing throughout the load hold period.

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

4. The maximum test load is sustained without reaching the failure point (pullout). The failure point shall be the point where the movement of the test soil nail continues without an increase in the load. The failure load corresponding to the failure point shall be recorded as part of the test data.

B. Proof test nails may be incorporated into the production nail schedule provided that (1) the unbonded length of the nail hole has not collapsed during testing, (2) the minimum required hole diameter has been maintained, and (3) the test nail length is equal to or greater than the scheduled production nail. Test nails meeting these requirements shall be completed by grouting the unbonded length. Maintaining the unbonded length for subsequent grouting is the Contractor's responsibility. If the unbound length of production test nails cannot be grouted subsequent to testing due to caving conditions or other reasons, the Contractor shall replace the test nail with a similar production nail at his cost and to the satisfaction of Engineer.

3-11 TEST NAIL REJECTION

A. Engineer may require that the Contractor replace some or all of the installed production nails between the failed test and the adjacent passing proof test nail. Alternatively, Engineer may require that additional proof testing be conducted based on the results of the nail tests.

3-12 SITE MONITORING

A. The Contractor shall visit the site prior to any construction activities, observe and document the preconstruction condition of all structures, infrastructure, sidewalks, roadways, and all other facilities adjacent to the site. Documentation shall be submitted to the Engineer and Contracting Authority prior to the start of excavation. The Contractor shall make daily visual observation for signs of ground or building movements in the vicinity of each working front. The Contractor shall notify Engineer within 24 hours both verbally and in writing, if signs of movement such as new cracks in structures, increased size of old cracks or separation of joints in structures, foundations, streets or paved and unpaved surfaces are observed.

B. Engineer may direct the Contractor to monitor particular structures or areas more frequently using crack monitoring devices, or additional temporary bench marks.

3-13 SHOTCRETING

A. After each stage cut, in anticipation of shotcreting, clean surfaces of all loose material, mud, rebound from previously placed shotcrete and other foreign matter that will prevent bond of shotcrete. Dampen surface before shotcreting. Install permanent drainage as specified in the submitted plans. Connect drainage system at the bottom of the wall in such a manner as to carry the water away from the toe. Use weep holes, horizontal drains, or other methods to control seepage. Where used, weep holes shall be 2 feet long, 2 inches in diameter, slotted drain pipe (Schedule 40 PVC) placed in predrilled holes sloped 5% to

drain. During placement of shotcrete, the weep holes shall be protected against contamination to ensure proper functioning.

Apply shotcrete with the same equipment and the same technique as used to construct the approved test panels. Nozzle operators constructing the test panels area to be the same operators used in placing shotcrete in the work. Thickness measuring pins shall be installed on 5 foot centers in each direction. The pins shall be non-corrosive. Other methods to establish if the required minimum thickness of shotcrete is being applied may be approved if the contractor can satisfactorily demonstrate the reliability of these other methods.

When a layer of shotcrete is to be covered, it shall first be allowed to develop its initial set. Then, all laitance, loose material, and rebound must be removed by brooming or scraping. Remove all laitance which has been allowed to take final set by sandblasting and thoroughly clean the surfaces.

Firmly position the wire fabric to prevent vibration while the shotcrete is being applied. Lap mesh one-and-a-half squares in both directions. Tie wires shall be bent flat in the plane of the mesh and not form large knots. A minimum cover of 2 inches of shotcrete shall be required.

Control thickness, method of support, air pressure and water content of shotcrete to preclude sagging or sloughing off.

The shotcrete shall be applied from the bottom up to prevent accumulation of rebound on the surface still to be covered. Shotcrete shall emerge from the nozzle in a steady uninterrupted flow.

Check for hollow areas by sounding with a hammer. Use approved methods to correct deficient areas. Discontinue shotcreting or provide suitable means to screen the nozzle stream if wind or air currents cause separation of the stream during placement. Deficient areas shall be corrected at the Contractor’s experience.

First fill horizontal and vertical corners and any area where rebound cannot escape or be blown free.

Hold nozzle at such distance and angle to place material behind reinforcement before material is allowed to accumulate on its face. Do not place shotcrete through more than one layer of reinforcing steel rods or mesh in one application unless demonstrated by preconstruction tests that steel can be properly encased.

Construction joints shall be tapered to a thin edge, and the surface of such joints shall be thoroughly wetted before any adjacent section is placed.

Repair surface defects as soon as possible after initial placement of the shotcrete. All shotcrete which lacks uniformity, exhibits segregation, honeycombing, or lamination, or which contains any dry patches, slugs, voids, or sand pockets shall be removed and replaced with fresh shotcrete.

Do not repair core holes with shotcrete. Fill solid with patching mortar, after cleaning and thoroughly dampening.

Use the following precautions during shotcreting:

1. Do not use rebound or previously expended material in the shotcrete mix.
2. The area to which shotcrete is to be applied shall be clean and free of rebound or overspray.
3. Discontinue shotcreting when the ambient temperature drops below 38° F or when the shotcrete cannot be adequately maintained in excess of 38° F.
4. Discontinue shotcreting in heavy rains or in the presence of runoff.

After the shotcrete surface has attained its initial set, finish as specified in 2-1 E.8, cure in accordance with 2-1 E.9 of these specifications.

4-1 Method of Measurement

The soil nailed wall will be measured in square feet of the shotcrete area, exposed above finish grade, complete and accepted in the final work. All soil nailing, shotcrete, subgrade or foundation work below finish grade shall be incidental. The net area lying in a plane of the outside front face of the structure as shown on the plans will be measured. The final pay quantity shall be the design quantity increased or decreased by authorized changes.

5-1 Basis of Payment

The accepted quantities of soil nailed wall will be paid for at the contract unit price per square foot of exposed wall face above finish grade. The payment shall be full compensation for all labor, equipment, materials, material tests, field tests and incidentals necessary to acceptably design, fabricate, excavate and construct the soil nailed wall in accordance with all requirements of this specification and the contract documents.