Add the following Section:

SECTION 517

SOIL NAIL WALLS

517-1.01 DESCRIPTION.

This Work consists of constructing soil nail walls. A soil nail system is a structural system used to transfer tensile loads to soil. A soil nail system may also be specified in the Plans as a nail. A soil nail system includes all steel reinforcing bars, anchorage devices, grout, post grouting tubes, coatings, sheathings, and couplers if used.

517-2.01 MATERIALS. Use materials that conform to the following:

Shotcrete	Section 501
Pre-cast concrete fascia panels	Section 501
Bearing Plates, Nuts	Section 504
Weep hole drains	Subsection 511-3.01
Expansion Joints	Section 516
Gutter (Type I or II)	Section 609
Precast traffic barrier	Section 614
Drainage geotextile	Section 631
Prefabricated drainage mat	Section 631
4" Frost Insulation	Section 635
Cement	Section 701
Grout	Subsection 701-2.03
Aggregates	Section 703
Gravel backfill for drains	Subsection 703-2.10
Pipe and perforated pipe	Section 706
Reinforcing Steel	Section 709
Wire Mesh	Section 710
Admixtures	Subsection 711-2.02
Structural Steel	Section 716

Use Frost Insulation with a minimum R-value of 5 per inch of thickness at 25°F (as determined by ASTM C 518).

Use centralizers fabricated from plastic, steel, or material which is nondetrimental to the prestressing steel. Do not use timber.

Use a grout as required by Subsection 701-2.03 with the minimum compressive strength as required by soil nail manufacturer and as approved by engineer.

For soil nails use deformed steel reinforcing bars conforming to AASHTO M 31, Grade 60 minimum. Do not splice the soil nails. Thread the soil nails at the bearing plate end a minimum of six inches. Use continuous spiral deformed ribbing for threading. Alternatively, threads may be cut into the soil nail if the bar size is increased to the next larger size from the size specified in the Plans at no additional cost to the Department.

Fabricate tendon encapsulation, to provide additional corrosion protection, from one of the following:

1. High density corrugated polyethylene (PE) tubing conforming to the requirements of ASTM D 3350 Class PE335520C or Class PE335400C, ASTM D 1248, and AASHTO M 252 and having a nominal wall thickness of 40 mils.

2. Corrugated, polyvinyl chloride (PVC) tubing conforming to ASTM D 1784, Class 13464-B, and having a nominal wall thickness of 40 mils.

Center the soil nails within the sheathing with a minimum 0.2-inch grout cover over the soil nail inside the sheath. Construct the encapsulation at the factory under controlled conditions. Do not field construct the encapsulation.

Use epoxy-coated reinforcing steel bars as specified in Section 503 and Section 709. Bars shall be coated according to AASHTO M 284 with the additional following modifications:

1. Steel reinforcing bar acceptable for coating is ASTM A 706.
2. The thickness of epoxy coating shall be 10 mils plus or minus 2 mils.

Weld shear studs in accordance with Section 504.

Construct the concrete fascia panels in accordance with Section 501, Class A concrete and the details in the Plans.

CONSTRUCTION REQUIREMENTS

517-3.01 GENERAL.

Soil nailing consists of excavating to the layer limits shown in the Plans, drilling holes at the specified angle into the native material, placing and grouting epoxy-coated and encapsulated steel reinforcing bars (soil nails) in the drilled holes, placing prefabricated drainage material and steel reinforcement, and applying a shotcrete facing over the steel reinforcement. After completing the wall to full height, construct the concrete fascia as shown in the Plans, and in accordance with Subsection 501-3.07.
Install proprietary items used in the soil nailed structure in accordance with the manufacturer's recommendations. In the event of a conflict between the manufacturer's recommendations and these Specifications, these Specifications prevail.

517-3.02 QUALIFICATIONS.

Experience is required for completing at least 5 projects, within the last 5-years, involving construction of retaining walls using soil nails or ground anchors, or for completing the construction of 2 or more projects totaling at least 15,000-square feet of retaining wall with a minimum total of 500 soil nails or ground anchors. Assign an engineer with at least 3-years of experience in the design and construction of permanently anchored or nailed structures to supervise the work. Do not use consultants or manufacturer's representatives in order to meet the requirements of this section. Drill operators and on-site supervisors shall have a minimum of 1-year experience installing permanent soil nails or ground anchors.

517-3.03 SUBMITTALS.

Do not begin work on soil nail wall system until the Engineer has approved all of the required submittals. Submit the following information not less than 30-calendar days prior to the start of wall excavation.

1. A brief description of each project satisfying the Qualifications requirements with the Owner's name and current phone number.

2. A list of the following personnel assigned to this project and their experience with permanently anchored or nailed structures:

   a. Supervising Engineer

   b. Drill Operators

   c. On-site Supervisor(s) who will be assigned to the project.

3. The proposed detailed construction procedure that includes:

   a. Proposed method(s) of excavation of the soil and/or rock.

b. A plan for the removal and control of groundwater encountered during excavation, drilling, and other earth moving activities. Include a list of the equipment used to remove and control groundwater.

c Proposed drilling methods and equipment.

d. Proposed hole diameter(s).

e. Proposed method of soil nail installation.

f. Mix design for grout, procedures for placing the grout, and compressive strength of grout.

g. Shotcrete mix design with compressive strength test results.

h. Manufacturer's certificate of compliance for bearing plates, nuts, steel reinforcing bars, tendon encapsulation tubing, welded shear studs, centralizers and grout admixtures.

i. Procedures for placing the shotcrete (include placement in conditions when ground water is encountered).

j. Encapsulation system for additional corrosion protection selected for the soil nails and anchorages requiring encapsulation.

4. Detailed Working Drawings with details to clearly show the proposed system of jacking support, framing, and bracing to be used during testing.

5. Calibration data for each load cell, test jack, pressure gauge, stroke counter on the grout pump, and master gauge to be used. The calibration tests shall have been performed by an independent testing Laboratory, and tests shall have been performed within 60-calendar days of the date submitted. Do not commence testing or work until the Engineer has approved the load cell, jack, pressure gage, and master pressure gauge calibrations.

6. Certified mill test results and typical stress-strain curves along with samples from each heat, properly marked, for the soil nail steel. The guaranteed ultimate strength, yield strength, elongation, and composition shall be specified.

517-3.04 PRECONSTRUCTION CONFERENCE.

Schedule a soil nail preconstruction conference at least 5-working days prior to beginning any permanent soil nail work at the site to discuss construction procedures, personnel and equipment to be used. Those attending shall include:

1. (representing the Contractor) The superintendent, on site supervisors, and all foremen in charge of excavating the soil face, drilling the soil nail hole, placing the soil nail and grout, placing the shotcrete facing, and tensioning and testing the soil nail.

2. Representatives selected by the Engineer.

If the Contractor's key personnel change, or if the Contractor proposes a significant revision of the approved permanent soil nail installation plan, hold an additional conference before any additional permanent soil nail operations are performed.

517-3.05 EARTHWORK.

Establish the ground contour above the wall to its final configuration and slope as shown in the Plans prior to beginning excavation of the soil for the first row of soil nails. All excavation shall conform to Section 203.

Proceed with the excavation from the top down in a horizontal lift sequence with the ground level excavated no more than 2.5-feet below the elevation of the row of nails to be installed in that lift. Do not leave the excavated vertical wall face unshored more than 24-hours for any reason. A lift shall not be excavated until the nail installation and reinforced shotcrete placement for the preceding lift has been completed and accepted. After a lift is excavated, clean the cut surface of all loose materials, mud, rebound, and other foreign matter that could prevent or reduce shotcrete bond.

Cut the ground within a tolerable accuracy such that the required thickness of shotcrete can be placed within plus or minus 2 inches from the defined face of the wall, and over excavation does not damage overlying shotcrete sections by undermining or other causes.

517-3.06 SOIL NAILING.

Handle the encapsulated soil nails in such a manner to prevent large deflections or distortions during handling. When handling or transporting encapsulated soil nails, provide slings or other equipment necessary to prevent damage to the soil nails and the corrosion protection. The Engineer may reject any encapsulated nail which is damaged during transportation or handling. Damaged or defective encapsulation shall be repaired in accordance with the manufacturer's recommendations and as approved by the Engineer.

Soil nails shall be handled and sorted in such a manner as to avoid damage or corrosion. Prior to inserting a soil nail in the drilled hole, the Contractor and the Engineer will examine the soil nail for damage. If, in the opinion of the Engineer, the epoxy coating or bar has been damaged, the nail shall be repaired. If, in the opinion of the Engineer, the damage is beyond repair, the soil nail shall be rejected. If, in the opinion of the Engineer, the epoxy coating can be repaired, patch the coating with an Engineer approved patching material.

Drill holes for nails at the locations shown in the Plans plus or minus 6 inches. Locate the drill hole so that the longitudinal axis of the drill hole and the longitudinal axis of the nail are parallel. At the point of entry, install the soil nail shall be installed within plus or minus 3-degrees of the inclination from horizontal shown in the Plans, and the nail shall be within plus or minus 3-degrees of a line drawn perpendicular to the face of the wall unless otherwise shown in the Plans.

Do not use water or other liquids to flush cuttings during drilling, but air may be used. After drilling, install the nail and fully grout before placing the shotcrete facing. Insert the nail into the drilled hole with centralizers to the desired depth in such a manner as to prevent damage to the drilled hole, sheathing or epoxy during installation. The centralizers must provide a minimum of 0.5 inches of grout cover over the soil nail and must be spaced no further than 8-feet apart. When the soil nail cannot be completely inserted into the drilled hole without difficulty, remove the nail from the drilled hole and clean or redrill the hole to permit insertion. Do not drive or force partially inserted soil nails into the hole.

Immediately cease drilling and repair of all damages if subsidence or any other detrimental impact of drilling occurs. Repair in a manner approved by the Engineer at no additional cost to the Department. If caving conditions are encountered, no further drilling will be allowed until the Contractor selects a method to prevent ground movement. Use temporary casing or other methods to control ground movement, as approved by the Engineer. Remove temporary casings for the nail holes as the grout is being placed.

Where necessary for stability of the excavation face, a sealing layer of shotcrete may be placed before drilling is started, or drilling and grouting of nails through a stabilizing berm of native soil at the face of the excavation is permissible. Extend the stabilizing berm horizontally from the soil face and from the face of the shotcrete a minimum distance of 1-foot, and cut down from that point at a safe slope, no steeper than 1H:1V unless approved by the Engineer. Excavate the berm to final grade after installation and full length grouting of the nails. Repair or replace nails damaged during berm excavation, at no added cost to the Department.

If sections of the wall are constructed at different times than the adjacent soil nail sections, use stabilizing berms, temporary slopes, or other measures, as approved by the Engineer, to prevent sloughing or failure of the adjacent soil nail sections.

If cobbles and boulders are encountered at the soil face during excavation, remove all cobbles and boulders that protrude from the soil face into the design wall section and fill the void with shotcrete.

Produce grout free of lumps and undispersed cement. Equip the pump with a pressure gauge near the discharge end to monitor grout pressures. Provide a pressure gauge capable of measuring pressures of at least 150-psi or twice the actual grout pressures used by the Contractor, whichever is greater. Provide grouting equipment that enables the grout to be pumped in 1 continuous operation. Inject the grout from the lowest point of the drilled hole. Pump grout through grout tubes after insertion of the soil nail. Record the quantity of the grout and the grout pressures during installation. Control grout pressures and grout takes to prevent excessive ground heave.

Achieve the specified minimum design load transfer (DLT_{min}) within the range of drilled nail lengths (L_{min} to L_{max}) indicated in the Plans. Post-grouting is defined as injecting grout under high pressure after the initially placed soil nail grout has hardened.

517-3.07 SHOTCRETE FACING.

Prior to placing shotcrete on an excavated layer, vertically center prefabricated drainage mat between the columns of nails as shown in the Plans. Install the prefabricated drainage mat in accordance with the manufacturer's recommendations. Place the permeable drain side against the exposed soil face. Install the prefabricated drainage mat after each excavation lift and hydraulically connect with the prefabricated drainage mat previously placed, such that the vertical flow of water is not impeded. Tape all joints in the prefabricated drainage mat to prevent shotcrete intrusion during shotcrete application.
Place steel reinforcing bars and welded wire fabric, and apply the shotcrete facing in accordance with Section 501 and the details shown in the Plans.

Install shotcrete to the minimum thickness as shown in the Plans. Additional thicknesses of shotcrete due to over excavation or irregularities in the cut face are subsidiary.

Secure each soil nail at the shotcrete facing with a steel plate as shown in the Plans. The plate shall be seated on a wet grout pad of a pasty consistency. The nut shall then be sufficiently tightened to achieve full bearing surface behind the plate. After the shotcrete and grout have had time to gain the specified strength, the nut shall be tightened with at least 100-foot-pounds of torque.

517-3.08 SOIL NAIL TESTING AND ACCEPTANCE.

Both verification and proof testing of the nails is required. Supply all materials, equipment, and labor to perform the tests and submit all test data to the Engineer. Soil nails used for verification tests and proof tests are not production soil nails, and will not be counted as part of the total required soil nails..

Provide testing equipment that includes a dial gauge or vernier scale capable of measuring to 0.001-inch of the ground anchor movement. Use a hydraulic jack and pump to apply the test load. The movement-measuring device shall have a minimum travel equal to the theoretical elastic elongation of the total nail length plus 1-inch. Align the dial gauge or vernier scale so that its axis is within 5-degrees from the axis of the nail and monitor with a reference system that is independent of the jacking system and excavation face. Use a jack and pressure gauge calibrated by an independent testing Laboratory as a unit. Calibrate each load cell, test jack and pressure gauge, grout pump stroke counter, and master gauge as specified in Section 517-3.03 item 5.

Graduate the pressure gauge in increments of either 100-psi or 2 percent of the maximum test load, whichever is less. Select the pressure gauge to place the maximum test load within the middle of the range of the gauge. The ram travel of the jack may not be less than the theoretical elastic elongation of the total length at the maximum test load plus 1-inch. Independently support and center the jack over the nail so that the nail does not carry the weight of the jack. Provide a second calibrated jack pressure gauge at the site. Calibration data shall provide a specific reference to the jack and the pressure gauge.

The loads on the nails during the verification and proof tests shall be monitored to verify consistency of load – defined as maintaining the test load within 5 percent of the specified value. Verification and proof test loads less than 20,000-pounds or sustained for 5 minutes or less shall be monitored by the jack

pressure gauge alone. Verification and proof test loads equal to or greater than 20,000-pounds and sustained for longer than 5 minutes shall be monitored with the assistance of an electric or hydraulic load cell. Provide the load cell, the readout device, and a calibration curve from the most recent calibration as specified in Section 517-3.03, item 5. The load cell shall be selected to place the maximum test load within the middle of the range of the load cell. The load cell shall be mounted between the jack and the anchor plate. 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.

Initially grout test nails no closer to the excavation face than the dimension shown in the Plans. After placing the grout, do not disturb the nail until the grout has reached strength sufficient to provide resistance during testing. Leave test nails in place after testing, with the exposed portion of the test nail cut and removed to 2 feet behind the excavated face or inside face of shotcrete. Backfill the drill holes for test nails with grout or nonstructural filler after testing on those test nails has been completed.

Perform load testing against a temporary reaction frame with bearing pads that bear directly against the existing soil or the shotcrete facing. Keep bearing pads a minimum of 12 inches from the edges of the drilled hole and distribute the load to prevent failure of the soil face or fracture of the shotcrete. Submit reaction frame working drawings to the Engineer for approval.

The soil nail load monitoring procedure for verification and proof test load greater than 20,000-pounds and sustained for longer than 5 minutes is as follows:

1. For each increment of load, attainment of the load shall be initially established and confirmed by the reading taken from the jack gauge.

2. Once the soil nail anchor load has been stabilized, based on the jack gauge reading, the load cell readout device shall immediately be read and recorded to establish the load cell reading to be used at this load. The load cell reading is intended only as a confirmation of a stable soil nail load, and shall not be taken as the actual load on the soil nail.

3. During the time period that the load on the soil nail is held at this load increment, monitor the load cell reading. Adjust the jack pressure as necessary to maintain the initial load cell reading. Jack pressure adjustment for any other reason will not be allowed.

4. Soil nail elongation measurements shall be taken at each load increment as specified in Sections 517-3.08A and 517-3.08B.

5. Steps 1 through 4 shall be repeated at each increment of load, in accordance with the load sequence specified in Sections 517-3.08A and 517-3.08B.

517-3.08A VERIFICATION TESTING.

For the purpose of soil nail verification testing, the Nail Test Load TL shall be the Design Load Transfer DLT_{min} as shown in the Plans and shall use the Contractor's proposed production nail lengths and installation methods. This shall include post-grouting if proposed for use.

Perform verification testing on nails installed within the pattern of production nails to verify the Contractor's procedures, hole diameter, and design assumptions. No drilling or installation of production nails will be permitted in any ground unit unless successful verification testing of anchors in that unit has been completed and approved by the Engineer, using the same equipment, methods, nail inclination, nail length, and hole diameter as planned for the production nails. Changes in the drilling or installation method may require additional verification testing as determined by the Engineer and at no additional expense to the Department. Verification tests may be performed prior to excavation for the soil nail wall.

Successful verification tests are required within the limits as specified in the Special Provisions. Test nail locations within these limits shall be at locations selected by the Engineer.

The design details of the verification testing, including the system for distributing test load pressures to the excavation surface and appropriate nail bar size and reaction plate, shall be developed by the

Contractor, subject to approval by the Engineer. The intent is to stress the bond between the grout and the surrounding soil/rock to at least twice the design load transfer. Prior to beginning verification testing, measure and record the length of the nonbonded zone for each verification test soil nail. The bar shall be proportioned such that the maximum stress at 200 percent of the test load does not exceed 80 percent of the yield strength of the steel. Reposition the jack at the beginning of the test such that unloading and repositioning of the jack during the test will not be required. The verification tests shall be made by incrementally loading the nails in accordance with the following schedule of hold time:

AL 1-minute
0.25TL 10 minutes
0.50TL 10 minutes
0.75TL 10 minutes
1.00TL 10 minutes
1.25TL 10 minutes
1.50TL 60 minutes
1.75TL 10 minutes
2.00TL 10 minutes
AL = Nail Alignment Load
TL = Nail Test Load

The test load shall be determined by the following equation = Test Load (TL) = Bond Length (BL) X Design Load Transfer (DLT).

Apply the load in increments of 25 percent of the test load. Each load increment shall be held for at least 10 minutes. Measurement of nail movement shall be obtained at each load increment. The load-hold period shall start as soon as the load is applied and the nail movement with respect to a fixed reference shall be measured and recorded at 1-minute, 2, 3, 4, 5, 6, 10, 20, 30, 40, 50, and 60 minutes.
The Engineer will evaluate the results of each verification test and make a determination of the suitability of the test and of the proposed production nail design and installation system. Tests that fail to meet the design criteria will require additional verification testing or an approved revision to the proposed production nail design and installation system. If a nail fails in creep, retesting will not be allowed.

A verification tested nail with a 60-minute load hold at 1.50TL is acceptable if:

1. The nail carries the test load with a creep rate that does not exceed 0.08-inch per log cycle of time and is at a linear or decreasing creep rate.

2. The total movement at the test load exceeds 80 percent of the theoretical elastic elongation of the non-bonded length.

A pullout failure shall not occur for the verification test anchor at the 2.0TL maximum load. Pullout failure load is defined as the load at which attempts to increase the test load result only in continued pullout movement of the test nail without a sustainable increase in the test load.

517-3.08B PROOF TESTING.

Perform proof tests on proof test soil nails installed within the pattern of the production soil nails at the locations shown in the Plans. Install proof test soil nails using the same equipment, methods, nail inclination, nail length, and hole diameter as for adjacent production nails. Maintain the side-wall stability of the drill hole for the non-grouted portion during the test. Determine the bond length from the Nail Schedule and Test Nail Detail shown in the Plans.

Prior to beginning proof testing, measure and record the length of the nonbonded zone for each proof test soil nail.

Perform proof tests by incrementally loading the nail in accordance with the schedule below. Measure and record the anchor movement to the nearest 0.001-inch with respect to an independent fixed reference point in the same manner as for the verification tests at the alignment load and at each

increment of load. Monitor the load in accordance with Section 517-3.08. The scheduling of hold times is as follows:

AL 1-minute
0.25TL 5 minutes
0.50TL 5 minutes
0.75TL 5 minutes
1.00TL 5 minutes
1.25TL 5 minutes
1.50TL 10 minutes
AL = Nail Alignment Load
TL = Nail Test Load

Hold the maximum load in a proof test for 10 minutes. The load hold period starts as soon as the maximum load is applied and the nail movement with respect to an independent fixed reference shall be measured and recorded at 1, 2, 3, 4, 5, 6, and 10 minutes. The nail movement between 1-minute and 10 minutes may not exceed 0.04 inches. If the nail movement between 1 and 10 minutes exceeds 0.04 inch, hold the maximum load an additional 50 minutes. If the load hold is extended, record the nail movement at 20, 30, 40, 50, and 60 minutes. If a nail fails in creep, retesting will not be allowed.

A proof tested nail is acceptable if:

1. The nail carries the maximum load with less than 0.04 inches of movement between 1-minute and 10 minutes, unless the load hold extended to 60 minutes, in which case the nail would be acceptable if the creep rate does not exceed 0.08 inches per log cycle of time.

2. The total movement at the maximum load exceeded 80 percent of the theoretical elastic elongation of the non-bonded length.

3 The creep rate is not increasing with time during the load hold period.

If a proof test fails, the Engineer may direct the Contractor to replace some or all of the installed production nails between the failed test and an adjacent proof test nail that has met the test criteria. The Engineer may also require additional proof testing. All additional proof tests, and all installation of additional or modified nails, shall be performed at no additional expense to the Department.

517-3.09 CONCRETE FASCIA PANELS.

Provide the specified surface finish as noted, and to the limits shown, in the Plans to the exterior concrete surface.

517-3.10 RESTRICTIONS ON TEMPORARY EXCAVATIONS LOCATED NEAR SOIL NAIL WALLS.

Avoid excavations for installations of utilities or other facilities within the nail or anchor zone or at the toe of walls. Unless otherwise approved by the Engineer, comply with the following:

1. Parallel to and in front of wall: No continuous excavations are allowed parallel to the wall face unless they are located outside a vertical plane that is located one wall height in front of the wall. Parallel excavations within this zone are allowed provided the excavation does not extend below the bottom of the temporary wall facing.

2. Perpendicular to and in front of wall: For excavations made perpendicular to the wall face, do not excavate wider than the horizontal distance between soil nails; center excavations between nails. Perpendicular excavations wider than the anchor or nail spacing are allowed provided the excavation does not extend below the bottom of the temporary wall facing.

3. No grade changes of more than 6 inches are allowed within the nail or anchor zone behind walls. No construction surcharge loads are allowed behind the walls until all soil nails or anchors have been installed and the temporary wall facing constructed.

4. Cuts behind walls: Limit temporary cuts for utility construction or repair behind soil nail and anchored soldier pile walls to 3 feet in depth, the nail or anchor spacing in width, and must be centered between anchors.

517-4.01 METHOD OF MEASUREMENT.

Construction of soil nail wall shall be measured by the square foot of completed wall face, measured to the neat lines of the facing or panel as shown in the Plans.

If post-grouting of soil nails is proposed as part of the Contractor's soil nail installation methods, this work shall be considered incidental to completion of soil nail wall. Separate measurement for post-grouting of soil nails will not be made.

All work associated with furnishing and installing cement concrete gutter behind the wall as shown in the Plans shall be considered incidental to wall construction, and no separate measurement or payment for this work item shall be made.

517-5.01 BASIS OF PAYMENT.

All items required to construct soil nail wall, shall be considered incidental to wall construction, and no separate measurement or payment will be made for the items included but not limited to:

- All drilling, grouting, centralizers, bearing plates, welded shear connectors, nuts, and other Work required for installation of each soil nail;
- All costs in connection with successfully completing soil nail verification tests and soil nail proof tests as specified shall be included in the unit contract price per each for "Soil Nail Verification Test and Soil Nail Proof Test," including removal of the exposed portion of the test nail and backfilling the drilled hole with grout or nonstructural filler;
- All costs in connection with constructing the concrete fascia panels as specified, including all steel reinforcing bars, premolded joint filler, polyethylene bond breaker strip, joint sealant, PVC pipe for weep holes, and exterior surface finish;
- All costs in connection with adding shotcrete facing to fill voids left by cobbles and boulders;
- All costs in connection with excavation in front of the back face of the shotcrete facing.

Payment will be made under:

Pay Item No.	Pay Item	Pay Unit
517(1)	Soil Nail Wall	Square Foot