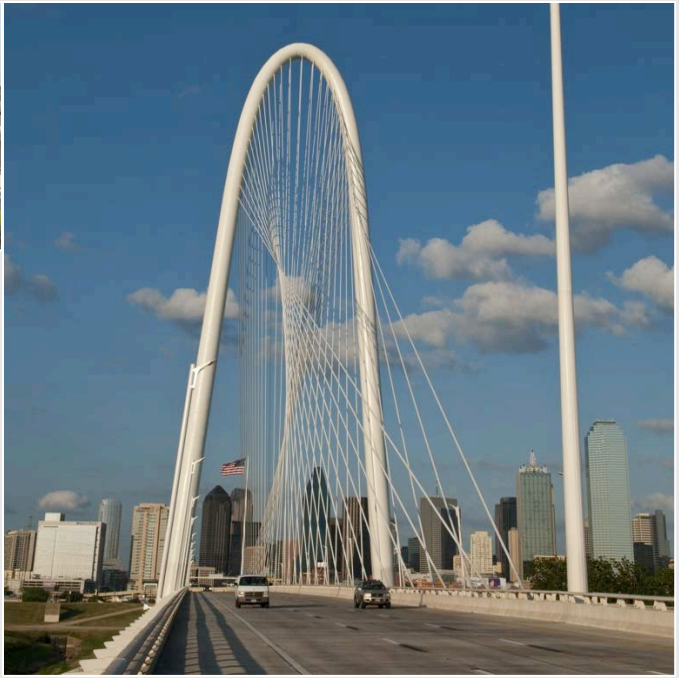
TEXAS DEPARTMENT OF TRANSPORTATION



SOIL NAIL WALL BASICS

John G. Delphia, P.E.

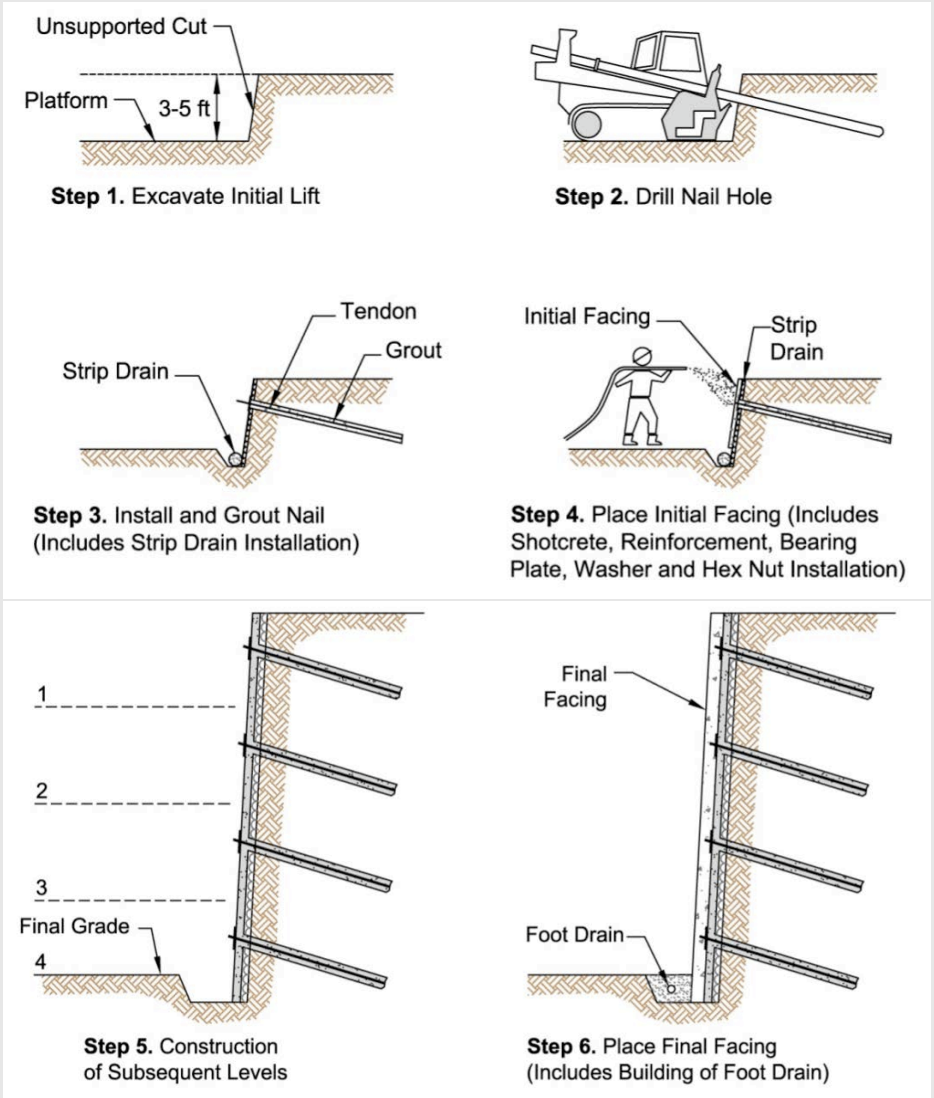
TxDOT Bridge Division

Geotechnical Branch

Soil Nail Basics

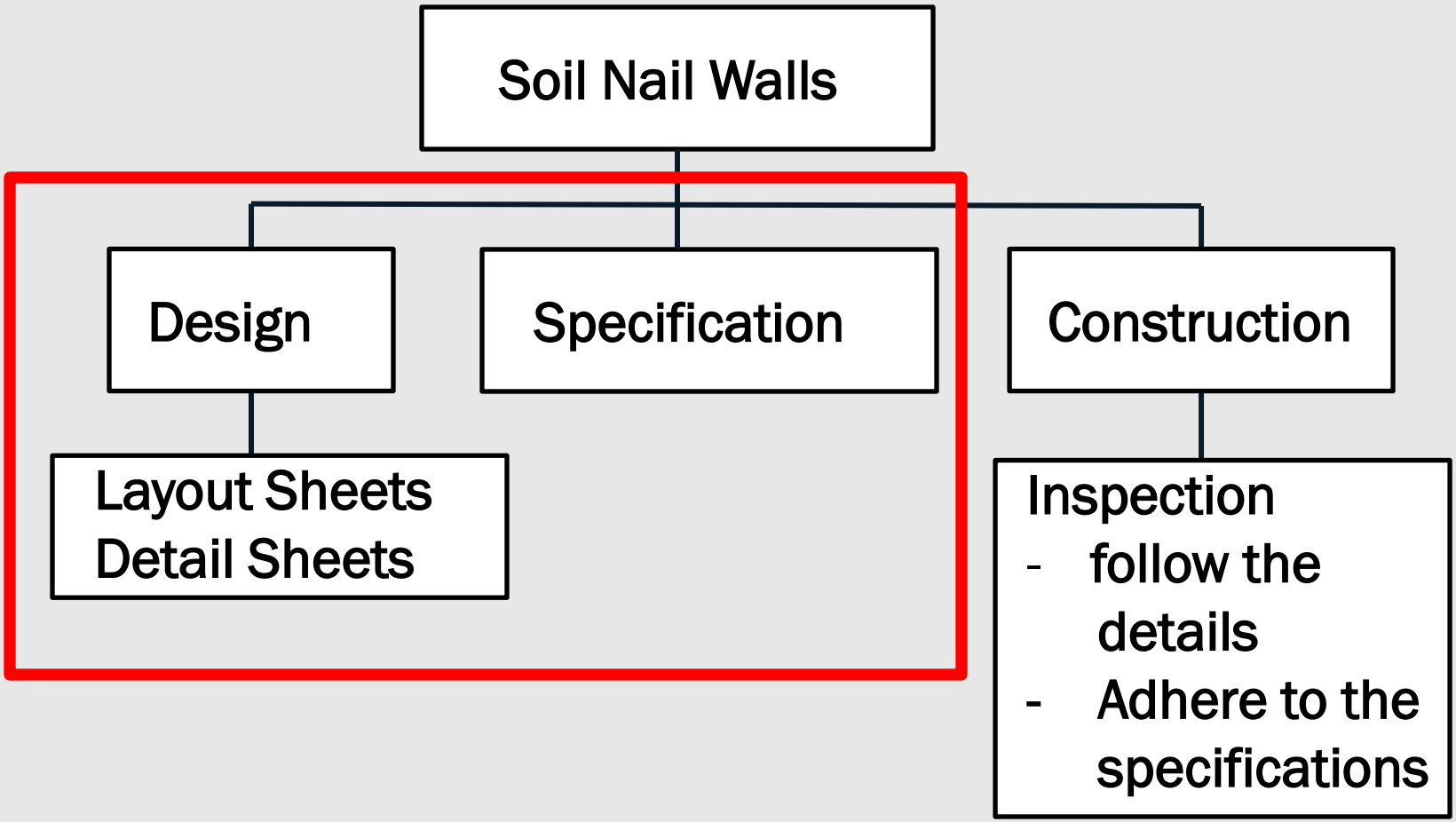
Soil Nail Walls

- Technique to reinforce and strengthen the soil
- Construction proceeds from the top down
- Nails (grouted steel bars) are passive reinforcement
- Nails limit the displacement of the soil



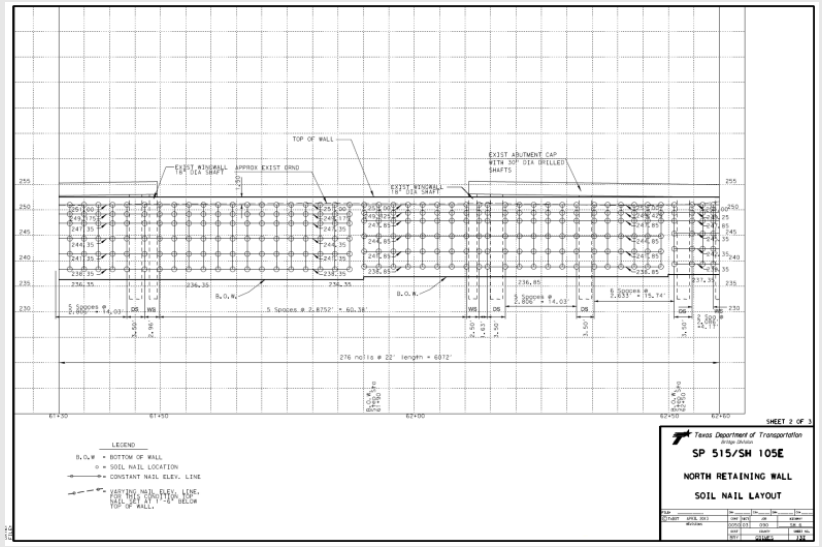
From: **FHWA GEC 007 February 2015**

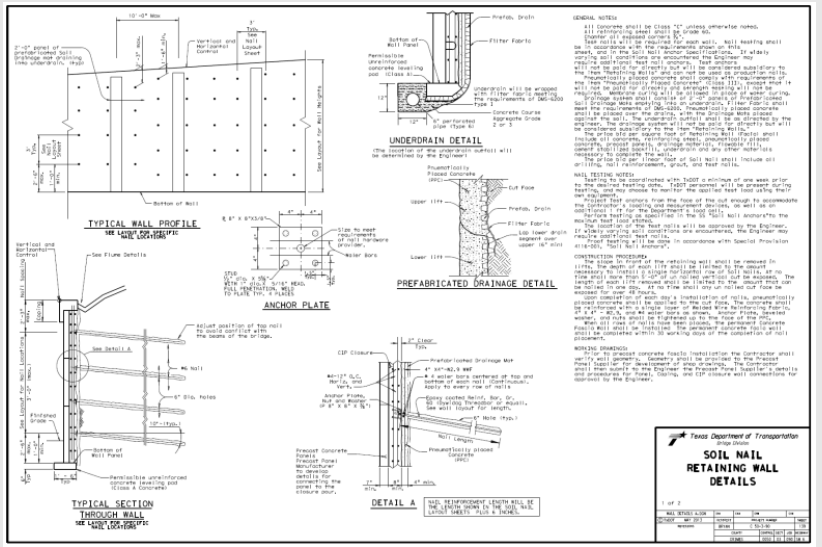
Soil Nail Basics



Soil Nail Basics

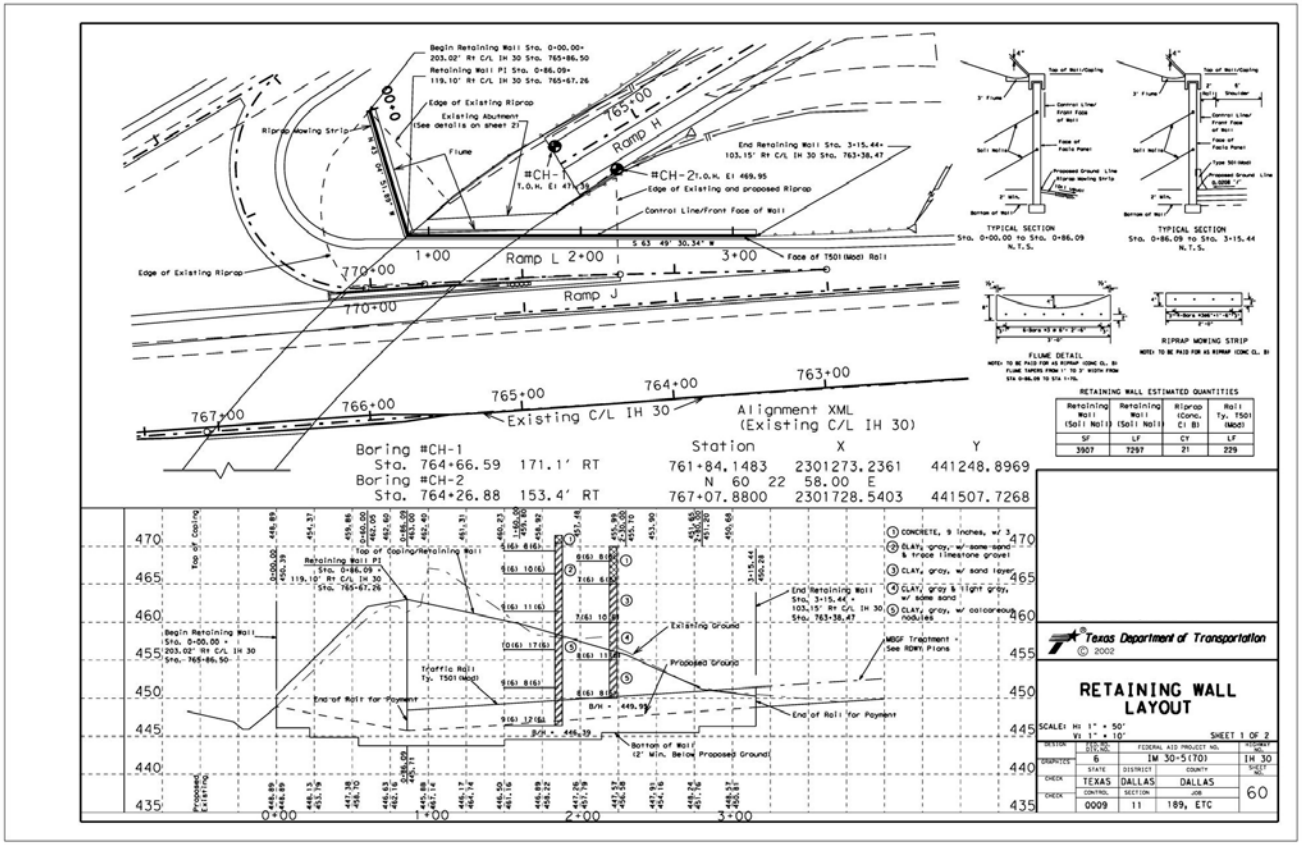
- Soil Nail Walls Need to Be Designed for the site conditions
- There Are Not Any Standards
- Not a Proprietary System.
- Complete details must be provided.





Wall Layout

- Soil borings through zone to be nailed
- Provide separation from bridge abutment where possible
- Limit base-of-wall embedment
- Consider future excavation at base of wall.



SOIL NAIL DESIGN

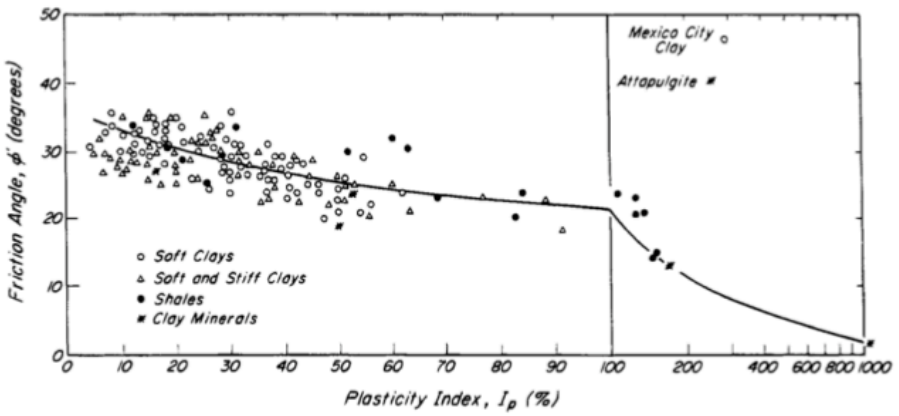
Design Tools

- FHWA Design Manual – **Soil Nail Walls Reference Manual** (GEC 7)

- Various Computer Programs are available:
  - GoldNail Computer Program
  - SnailZ Computer Program
  - SNAP-2 Computer Program

Soil Parameters

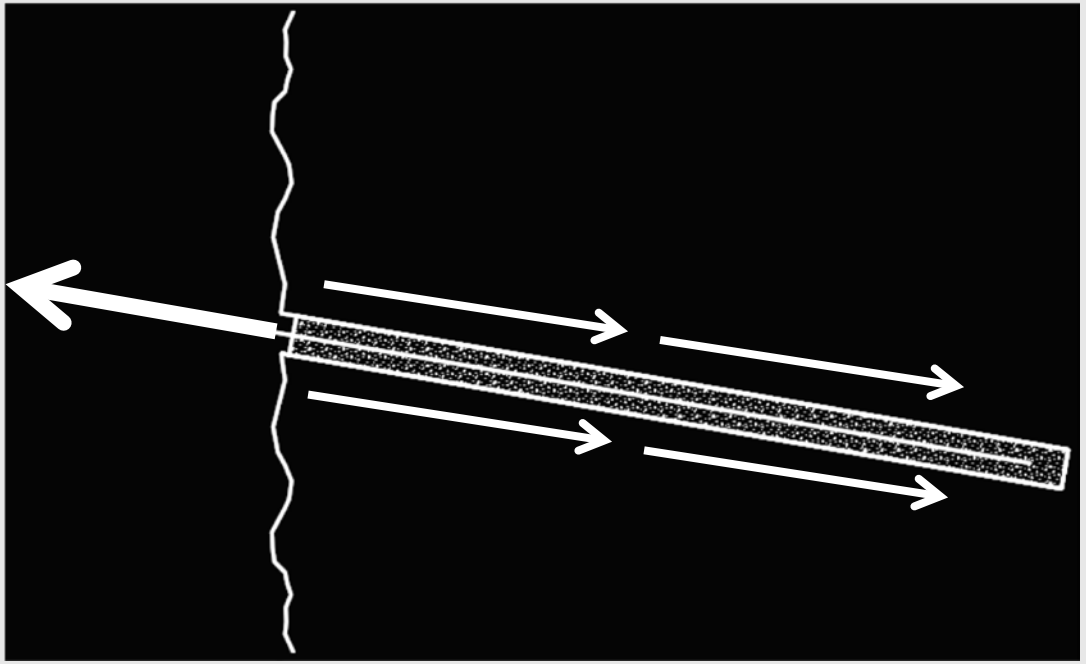
- Determine drained soil parameters from laboratory testing (difficult), correlation with PI, or experience.
- Drained Cohesion should be very low (0 - 100 psf)
- Drained Angle of Friction (ϕ') is normally between 24 and 34 degrees
- Drained soil parameters determine what portion of load is transferred to the nails from the face.



Graph. Relationship between friction angle and plasticity index (after Terzaghi, Peck, and Mesri 1996).

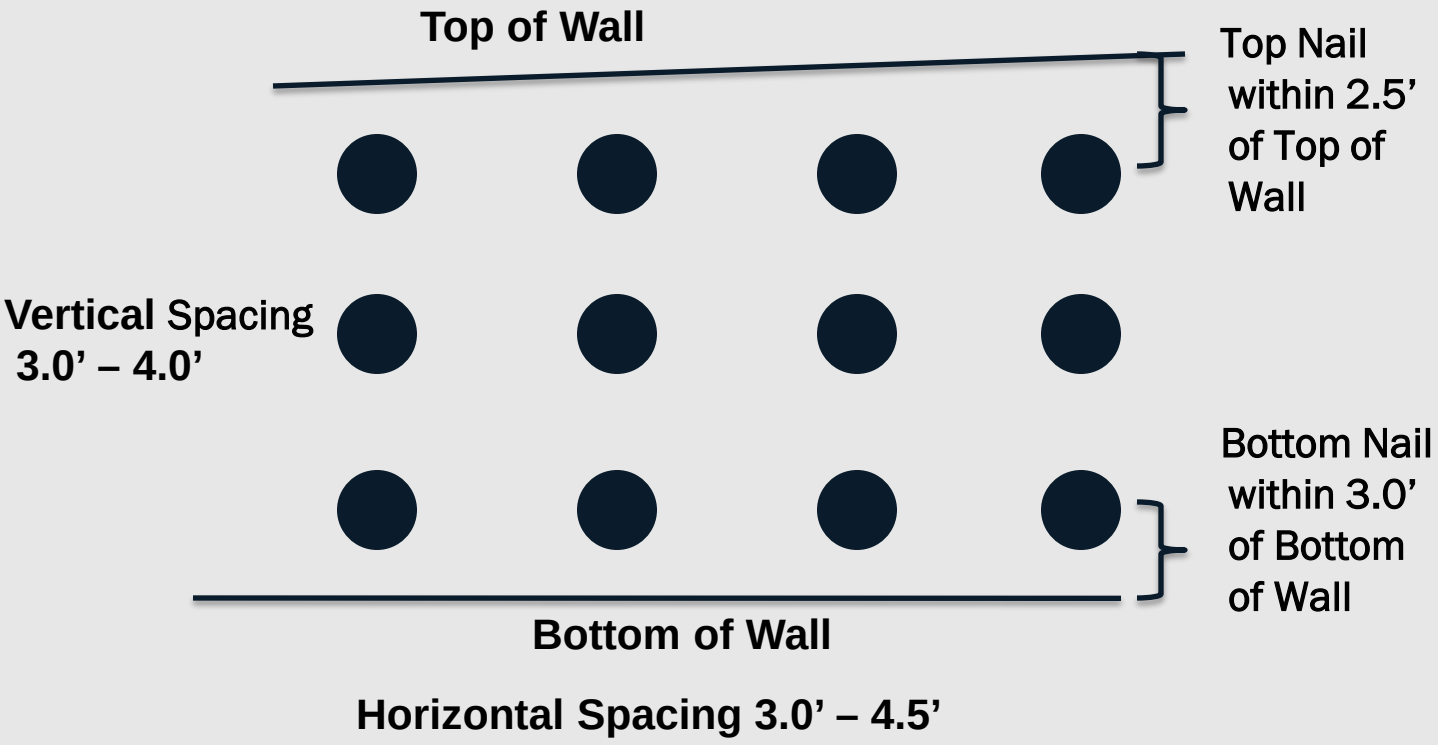
Soil Parameters

- Ultimate Pullout Resistance is the anticipated ultimate shear resistance per foot of nail
- Use Texas Cone Penetrometer (TCP) tests to determine the Ultimate Pullout Resistance
- Same method as calculating skin friction on a drilled shaft or pile



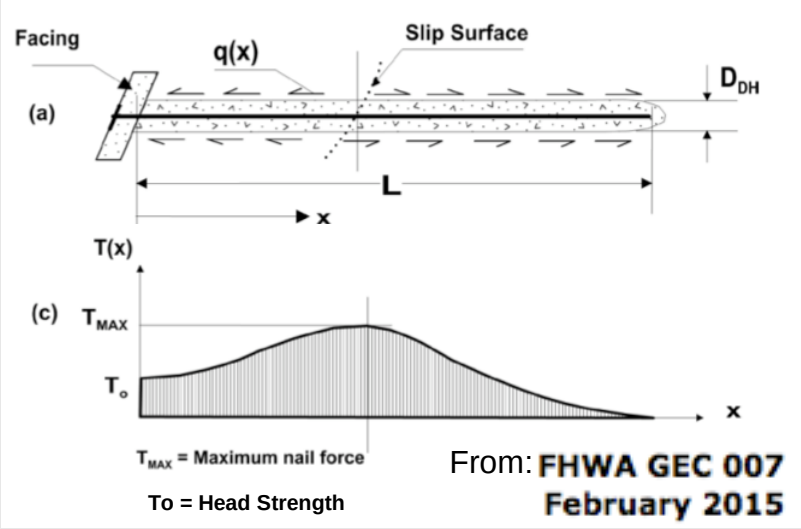
Nail Spacing Guidelines

- Nail Spacing impacts the loading on the soil nails
- For clay soils use a tighter spacing

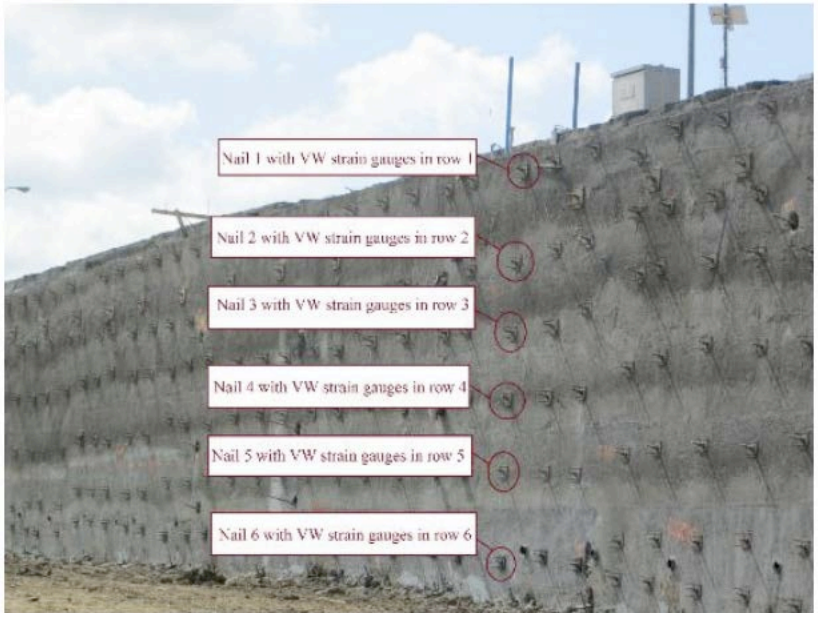


Head Strength

- Head Strength is defined as the capacity of the nail anchorage in the fascia
- High Head Strength shortens the nails and allows the lowest nails to carry a disproportionate amount of load
- Do not allow lowest anchors to carry the highest loads
- If required, adjust the head strength until the upper half of wall is carrying at least half of the total load



Soil Nail Basics

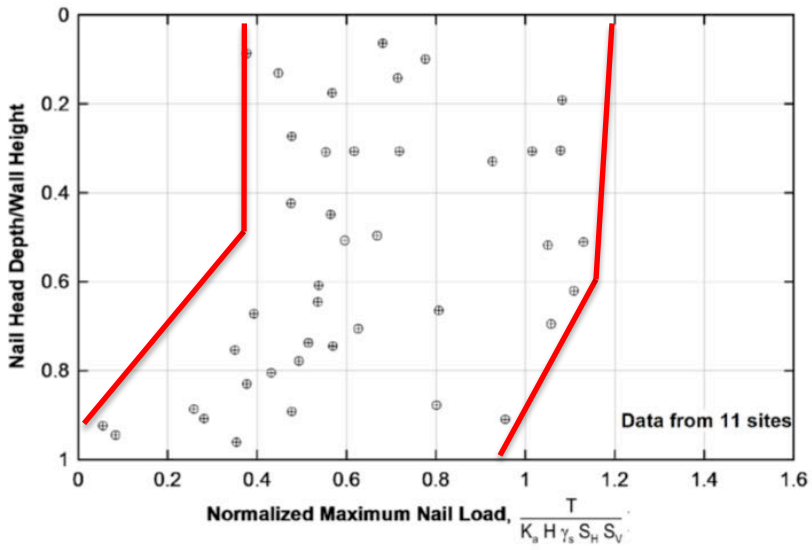


Service load in the nails at end of construction and one year after the end of construction

		Instrumented nails with VW strain gauges	
Nail No.	Design load (kips.)	Max. load at the end of construction (kips)	Max. service load one year after construction (kips)
Nail in first row	21	9.8	10.11
Nail in second row	18	13.11	12.57
Nail in third row	18	7.25	9.28
Nail in fourth row	18	7.47	8.01
Nail in fourth row	18	6.7	8.3
Nail in fourth row	18	1.2	6.9

TxDOT Monitored Soil Nail Wall

Full-scale wall tests show that the upper nails carry the highest loads



From: **FHWA GEC 007 February 2015**

Nail loads may increase over time in the wall (high PI clay soils)

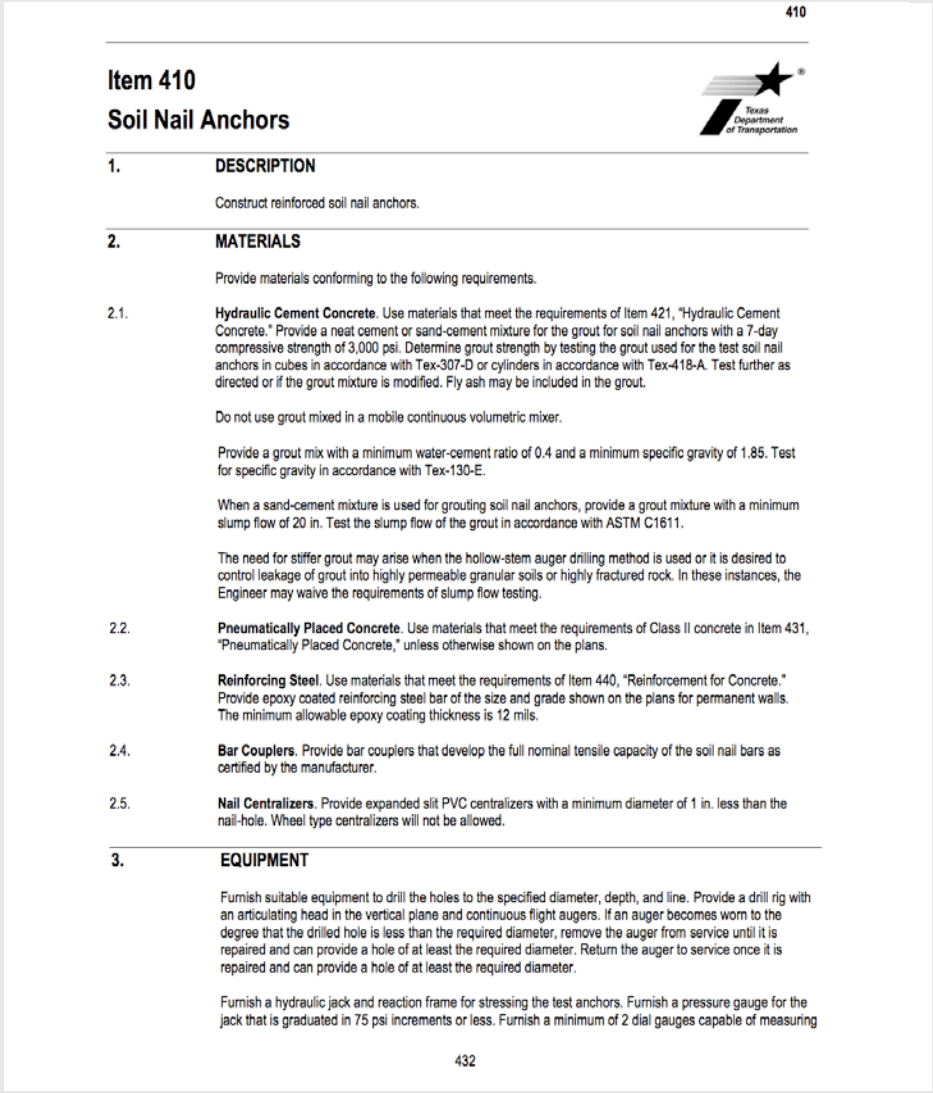
SOIL NAIL SPECIFICATION

Texas Department of Transportation

Standard Specifications for Construction and Maintenance of Highways, Streets, and Bridges

Adopted by the
Texas Department of Transportation

November 1, 2014



410

Item 410
Soil Nail Anchors

1. DESCRIPTION

Construct reinforced soil nail anchors.

2. MATERIALS

Provide materials conforming to the following requirements.

2.1. **Hydraulic Cement Concrete**. Use materials that meet the requirements of Item 421, "Hydraulic Cement Concrete." Provide a neat cement or sand-cement mixture for the grout for soil nail anchors with a 7-day compressive strength of 3,000 psi. Determine grout strength by testing the grout used for the test soil nail anchors in cubes in accordance with Tex-307-D or cylinders in accordance with Tex-418-A. Test further as directed or if the grout mixture is modified. Fly ash may be included in the grout.

Do not use grout mixed in a mobile continuous volumetric mixer.

Provide a grout mix with a minimum water-cement ratio of 0.4 and a minimum specific gravity of 1.85. Test for specific gravity in accordance with Tex-130-E.

When a sand-cement mixture is used for grouting soil nail anchors, provide a grout mixture with a minimum slump flow of 20 in. Test the slump flow of the grout in accordance with ASTM C1611.

The need for stiffer grout may arise when the hollow-stem auger drilling method is used or it is desired to control leakage of grout into highly permeable granular soils or highly fractured rock. In these instances, the Engineer may waive the requirements of slump flow testing.

2.2. **Pneumatically Placed Concrete**. Use materials that meet the requirements of Class II concrete in Item 431, "Pneumatically Placed Concrete," unless otherwise shown on the plans.

2.3. **Reinforcing Steel**. Use materials that meet the requirements of Item 440, "Reinforcement for Concrete." Provide epoxy coated reinforcing steel bar of the size and grade shown on the plans for permanent walls. The minimum allowable epoxy coating thickness is 12 mils.

2.4. **Bar Couplers**. Provide bar couplers that develop the full nominal tensile capacity of the soil nail bars as certified by the manufacturer.

2.5. **Nail Centralizers**. Provide expanded slit PVC centralizers with a minimum diameter of 1 in. less than the nail-hole. Wheel type centralizers will not be allowed.

3. EQUIPMENT

Furnish suitable equipment to drill the holes to the specified diameter, depth, and line. Provide a drill rig with an articulating head in the vertical plane and continuous flight augers. If an auger becomes worn to the degree that the drilled hole is less than the required diameter, remove the auger from service until it is repaired and can provide a hole of at least the required diameter. Return the auger to service once it is repaired and can provide a hole of at least the required diameter.

Furnish a hydraulic jack and reaction frame for stressing the test anchors. Furnish a pressure gauge for the jack that is graduated in 75 psi increments or less. Furnish a minimum of 2 dial gauges capable of measuring

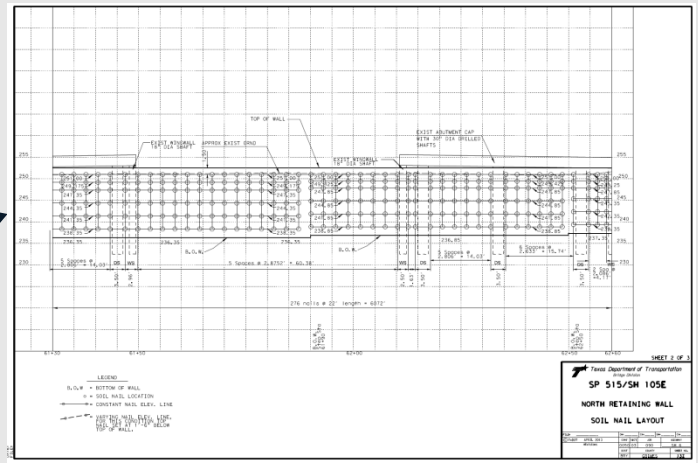
432

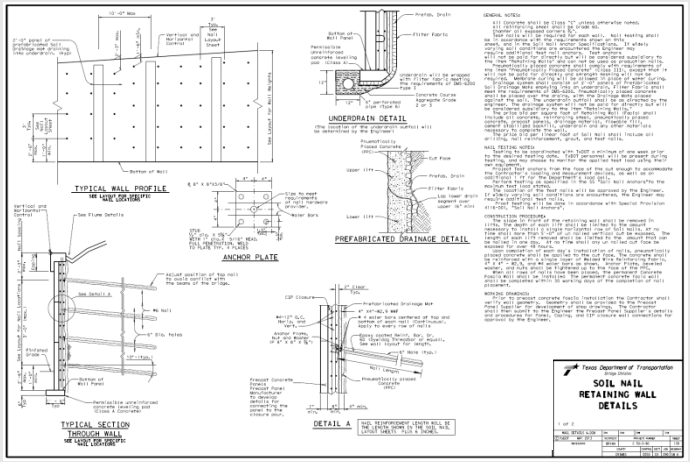
Specification is an updated version of the Statewide Special Specification 4116 and includes materials, equipment, construction, testing, measurement, and payment.

Soil Nail Basics

Design

Layout Sheets
Detail Sheets





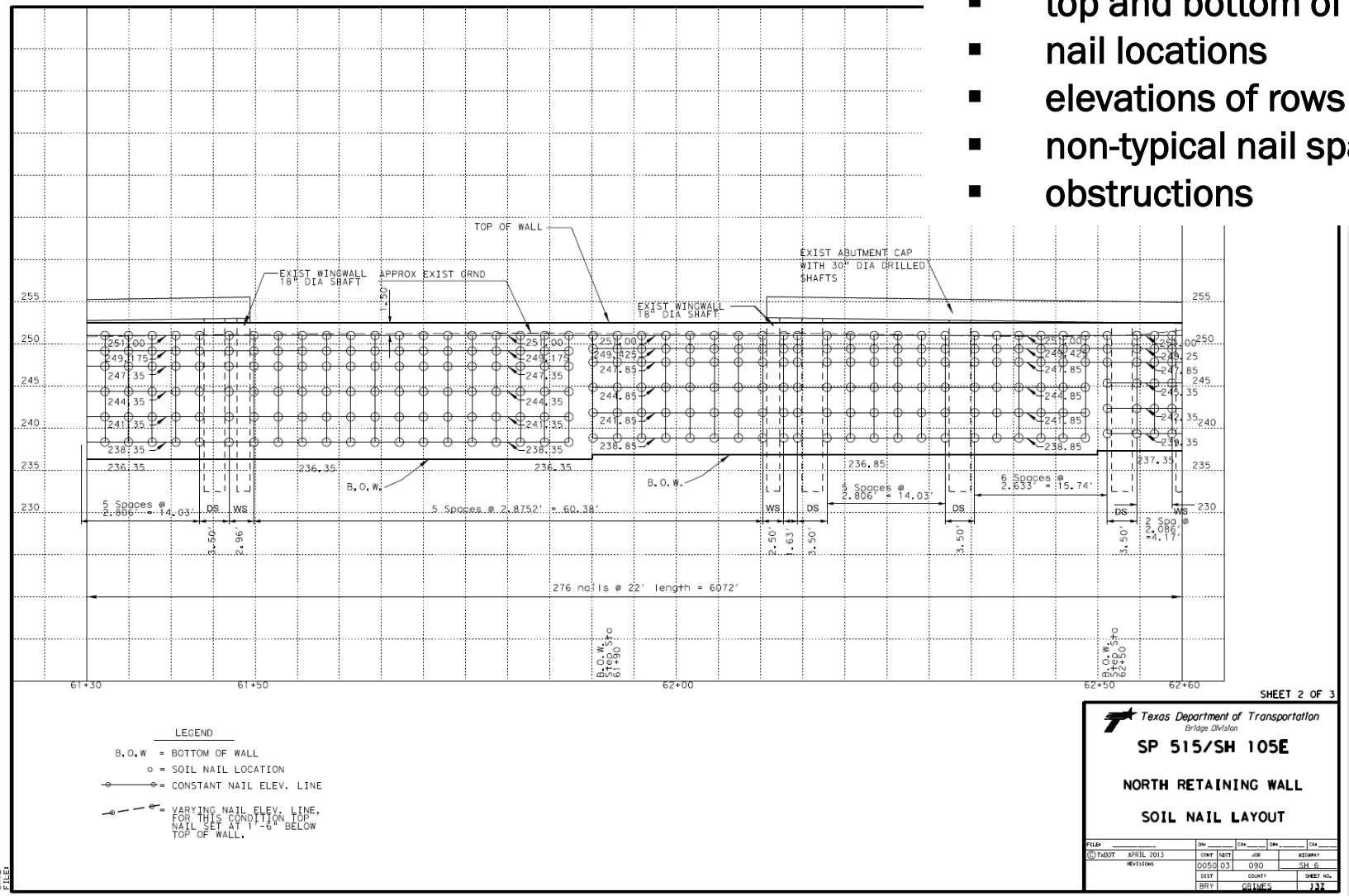
SOIL NAILED WALLS NEED TO BE DESIGNED FOR THE SITE CONDITIONS PRESENT

THERE ARE NOT ANY STANDARD DETAIL SHEETS FOR THEM

EACH WALL NEEDS TO BE TREATED INDIVIDUALLY

Soil Nail Basics

SOIL NAIL LAYOUTS



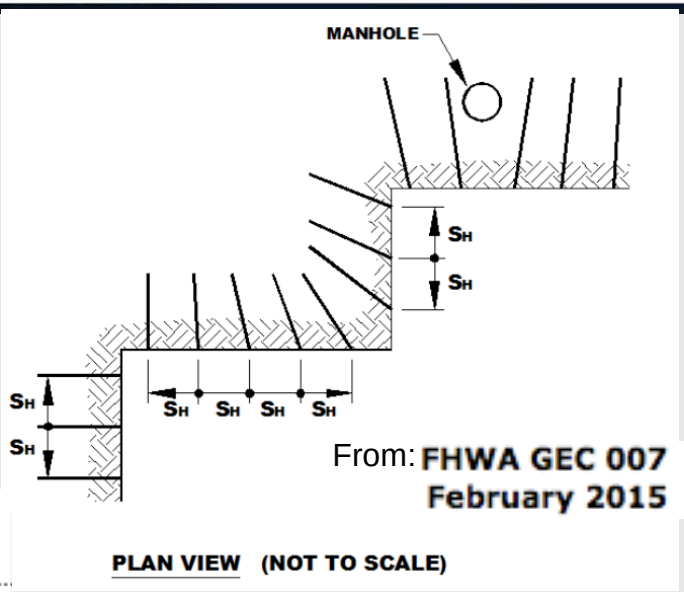
Identify the following:

- top and bottom of wall
- nail locations
- elevations of rows of nails
- non-typical nail spacing
- obstructions

SOIL NAIL LAYOUTS

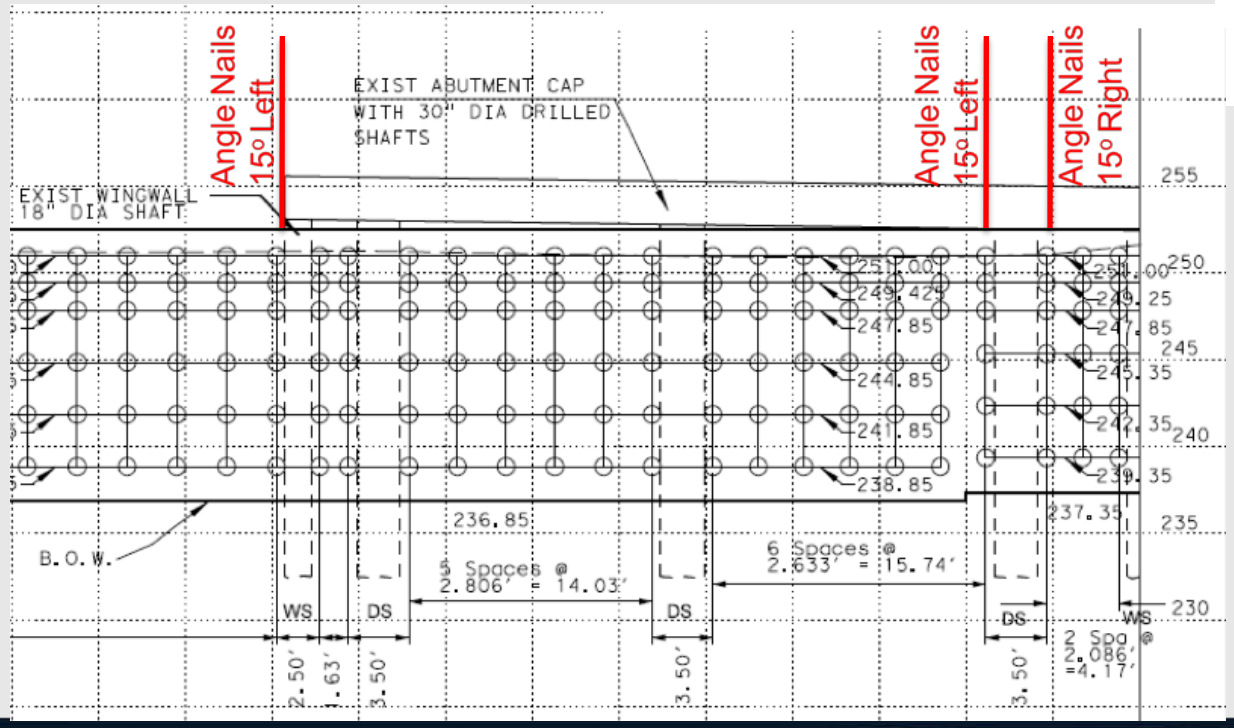
Sometimes soil nails may need to be angled.

The angle needs to be identified on the layout.

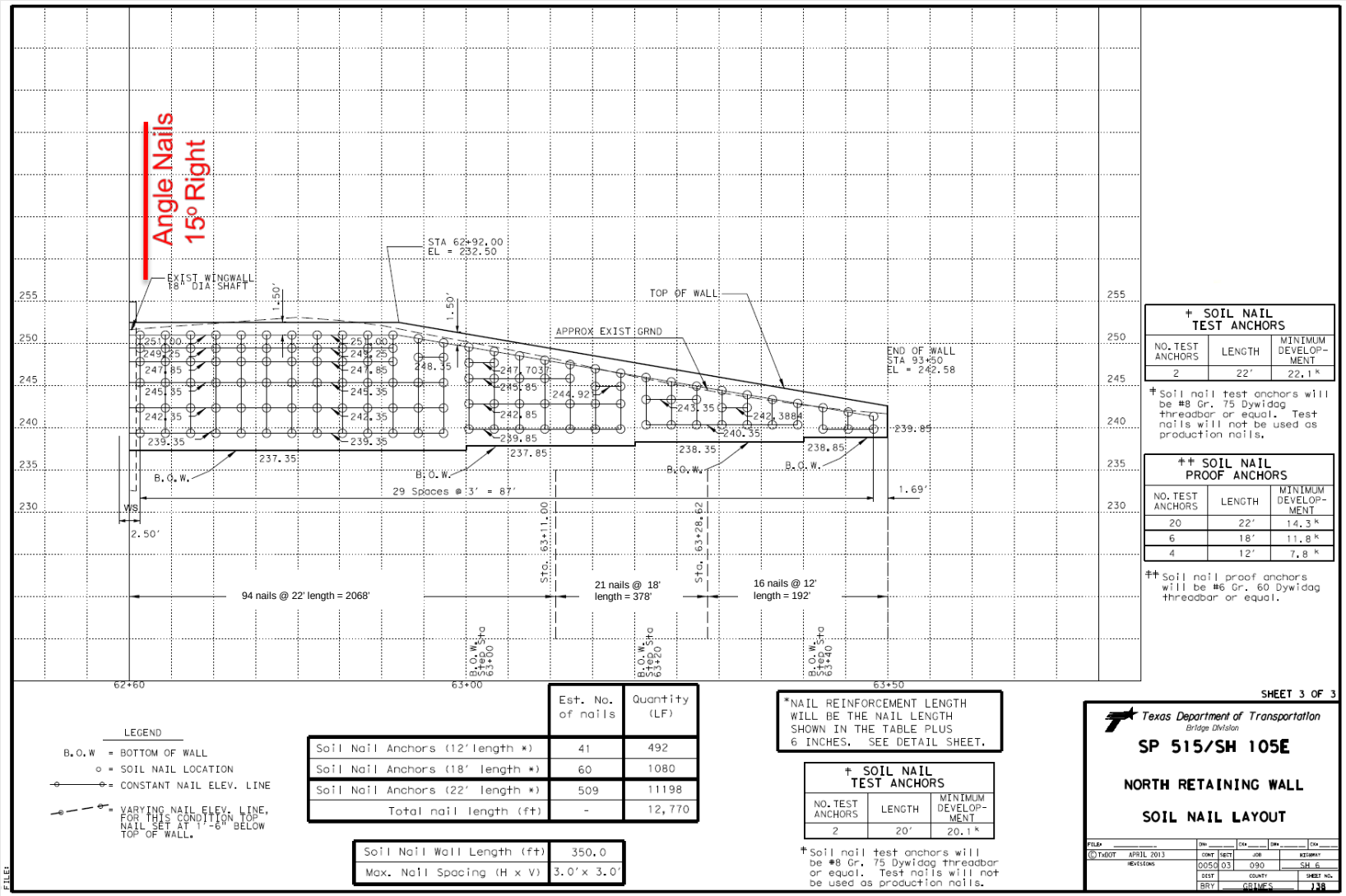


From: **FHWA GEC 007 February 2015**

PLAN VIEW (NOT TO SCALE)



SOIL NAIL LAYOUTS



† SOIL NAIL TEST ANCHORS		
NO. TEST ANCHORS	LENGTH	MINIMUM DEVELOP-MENT
2	22'	22.1 K

† Soil nail test anchors will be #8 Gr. 75 Dywidag threadbar or equal. Test nails will not be used as production nails.

†† SOIL NAIL PROOF ANCHORS		
NO. TEST ANCHORS	LENGTH	MINIMUM DEVELOP-MENT
20	22'	14.3 K
6	18'	11.8 K
4	12'	7.8 K

†† Soil nail proof anchors will be #6 Gr. 60 Dywidag threadbar or equal.

LEGEND

B.O.W = BOTTOM OF WALL
o = SOIL NAIL LOCATION
o—o = CONSTANT NAIL ELEV. LINE
o—o = VARYING NAIL ELEV. LINE, FOR THIS CONDITION TOP NAIL SET AT 1'-6" BELOW TOP OF WALL.

	Est. No. of nails	Quantity (LF)
Soil Nail Anchors (12' length *)	41	492
Soil Nail Anchors (18' length *)	60	1080
Soil Nail Anchors (22' length *)	509	11198
Total nail length (ft)	-	12,770

Soil Nail Wall Length (ft)	350.0
Max. Nail Spacing (H x V)	3.0' x 3.0'

*NAIL REINFORCEMENT LENGTH WILL BE THE NAIL LENGTH SHOWN IN THE TABLE PLUS 6 INCHES. SEE DETAIL SHEET.

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SHEET 3 OF 3

Texas Department of Transportation
Bridge Division

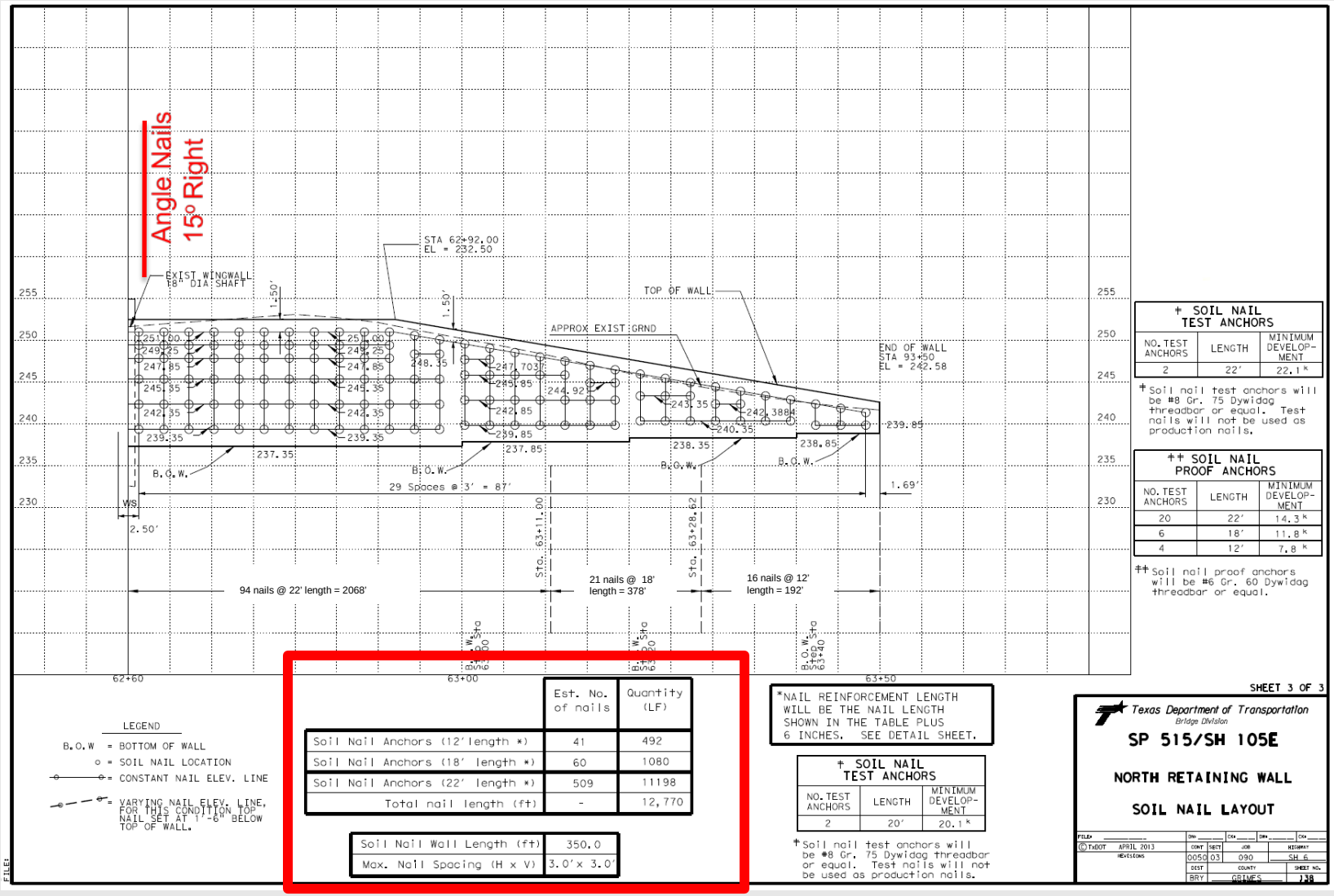
SP 515/SH 105E

NORTH RETAINING WALL

SOIL NAIL LAYOUT

FILE=	DW=	CK=	DW=	CK=
© TxDOT APRIL 2013	CONT	SECT	JOB	HIGHWAY
REVISIONS	0050	03	090	SH 6
	DIST	COUNTY		SHEET NO.
	BRY	GRIMES		138

SOIL NAIL LAYOUTS



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SHEET 3 OF 3

Texas Department of Transportation
Bridge Division

SP 515/SH 105E

NORTH RETAINING WALL

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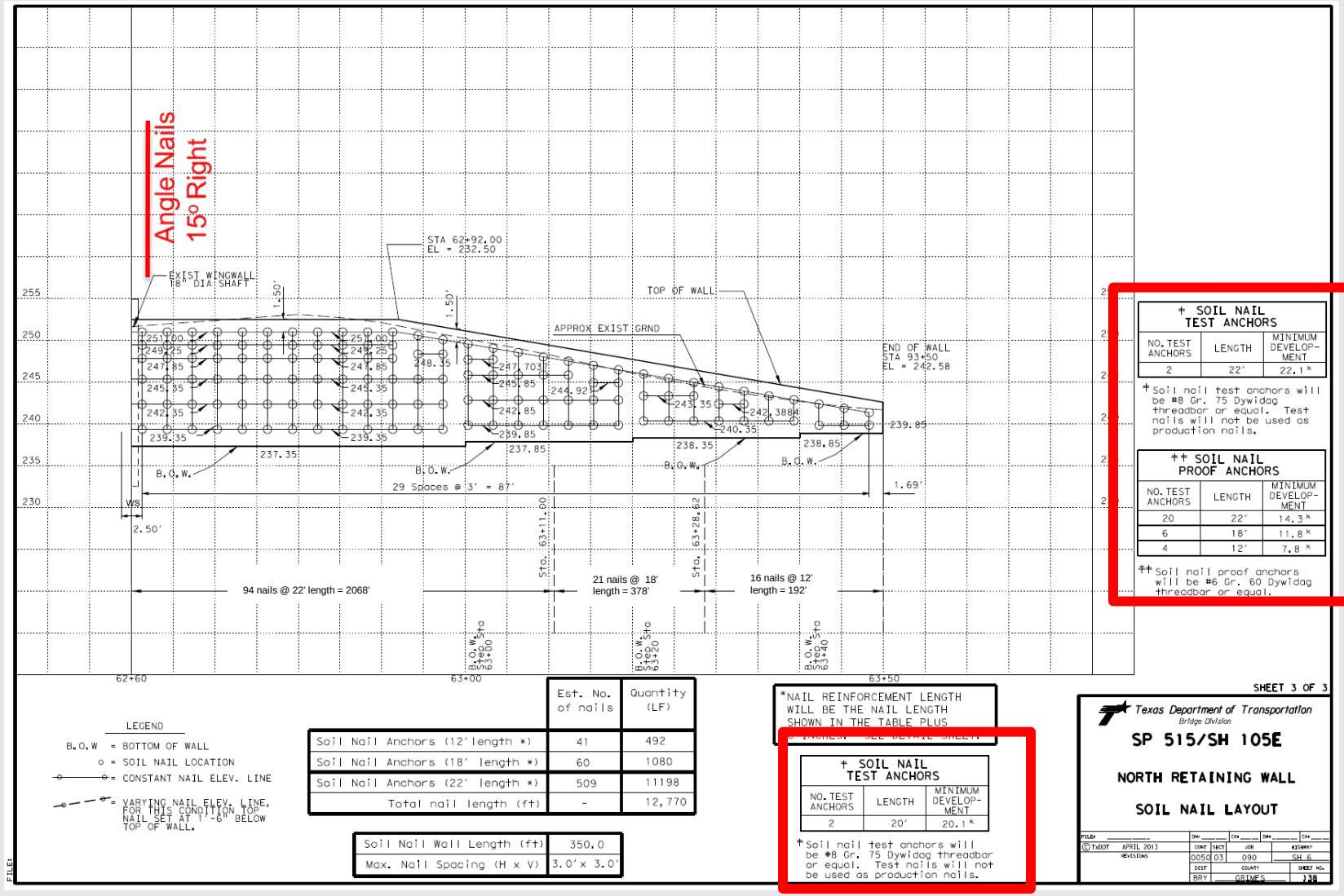
FILE=	DW=	CK=	DW=	CK=
© TxDOT APRIL 2013	CONT	SECT	JOB	HIGHWAY
REVISIONS	0050	03	090	SH 6
	DIST	COUNTY		SHEET NO.
	BRY	GRIMES		138

SOIL NAIL LAYOUTS



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SHEET 3 OF 3

Texas Department of Transportation
Bridge Division

SP 515/SH 105E

NORTH RETAINING WALL

SOIL NAIL LAYOUT

FILE:	DW:	CK:	DW:	CK:
© TxDOT APRIL 2013	CONT	SECT	JOB	HIGHWAY
REVISIONS	0050	03	090	SH 6
	DIST	COUNTY		SHEET NO.
	BRY	GRIMES		138

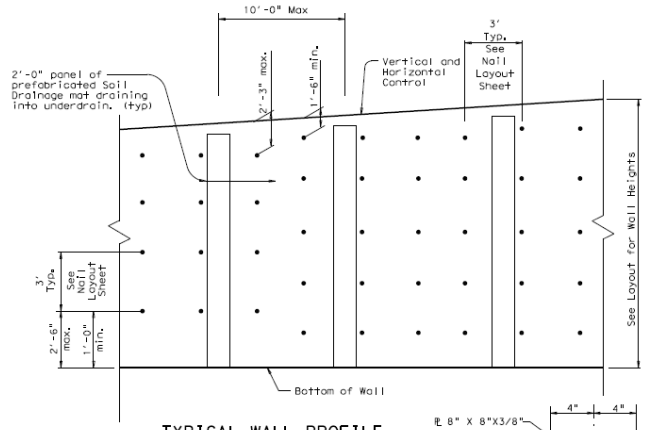
SOIL NAIL TESTS

TWO TYPES OF TESTS

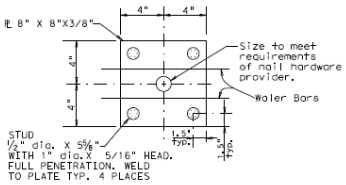
1. Verification Tests
   - these are performed prior to construction
   - on sacrificial soil nail anchors
   - tests both the strength of the soil and the Contractor's methods of installation

2. Proof Tests
   - these are performed on production soil nail anchors
   - performed to a lower load than verification nails
   - tests the Contractor's methods of installation

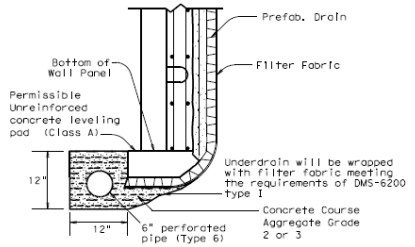
SOIL NAIL DETAIL SHEET



TYPICAL WALL PROFILE
SEE LAYOUT FOR SPECIFIC NAIL LOCATIONS

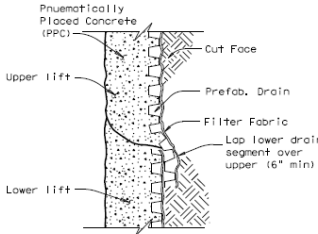


ANCHOR PLATE



UNDERDRAIN DETAIL

(The location of the underdrain outfall will be determined by the Engineer)



PREFABRICATED DRAINAGE DETAIL

GENERAL NOTES:

All Concrete shall be Class "C" unless otherwise noted.
All reinforcing steel shall be Grade 60.
Chamfer all exposed corners ¾".
Test nails will be required for each wall. Nail testing shall be in accordance with the requirements shown on this sheet, and in the Soil Nail Anchor Specifications. If widely varying soil conditions are encountered the Engineer may require additional test nail anchors. Test anchors will not be paid for directly but will be considered subsidiary to the item "Retaining Walls" and can not be used as production nails.
Pneumatically placed concrete shall comply with requirements of the item "Pneumatically Placed Concrete" (Class III), except that it will not be paid for directly and strength testing will not be required. Membrane curing will be allowed in place of water curing.
Drainage system shall consist of 2'-0" panels of Prefabricated Soil Drainage Mats emptying into an underdrain. Filter Fabric shall meet the requirements of DMS-6200. Pneumatically placed concrete shall be placed over the drains, with the Drainage Mats placed against the soil. The underdrain outfall shall be as directed by the engineer. The drainage system will not be paid for directly but will be considered subsidiary to the item "Retaining Walls."
The price bid per square foot of Retaining Wall (Facia) shall include all concrete, reinforcing steel, pneumatically placed concrete, precast panels, drainage material, flowable fill, cement stabilized backfill, underdrain and any other materials necessary to complete the wall.
The price bid per linear foot of Soil Nail shall include all drilling, nail reinforcement, grout, and test nails.

NAIL TESTING NOTES:

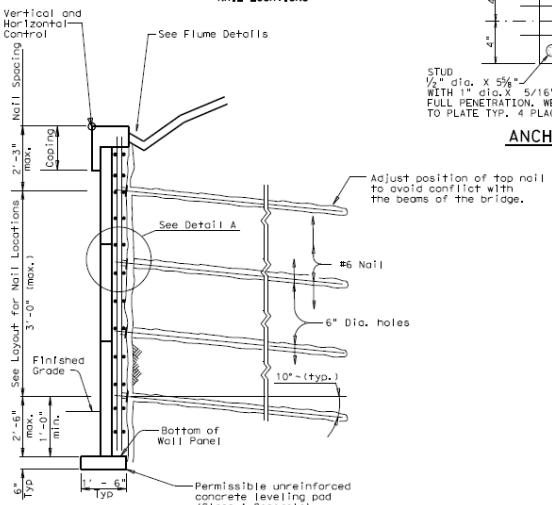
Testing to be coordinated with TxDOT a minimum of one week prior to the desired testing date. TxDOT personnel will be present during testing, and may choose to monitor the applied test load using their own equipment.
Project Test anchors from the face of the cut enough to accommodate the Contractor's loading and measurement devices, as well as an additional 1 ft for the Department's load cell.
Perform testing as specified in the SS "Soil Nail Anchors"to the maximum test load stated.
The location of the test nails will be approved by the Engineer. If widely varying soil conditions are encountered, the Engineer may require additional test nails.
Proof testing will be done in accordance with Special Provision 4116-001, "Soil Nail Anchors".

CONSTRUCTION PROCEDURE:

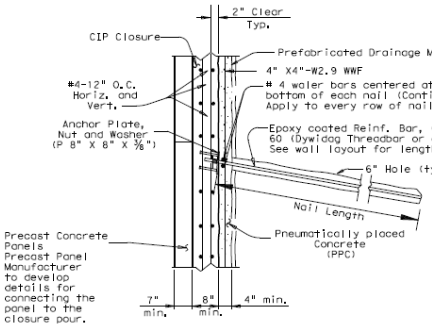
The slope in front of the retaining wall shall be removed in lifts. The depth of each lift shall be limited to the amount necessary to install a single horizontal row of Soil Nails. At no time shall more than 5'-0" of un nailed vertical cut be exposed. The length of each lift removed shall be limited to the amount that can be nailed in one day. At no time shall any un nailed cut face be exposed for over 48 hours.
Upon completion of each day's installation of nails, pneumatically placed concrete shall be applied to the cut face. The concrete shall be reinforced with a single layer of Welded Wire Reinforcing Fabric, 4" X 4" - W2.9, and #4 waler bars as shown. Anchor Plate, beveled washer, and nuts shall be tightened up to the face of the PPC.
When all rows of nails have been placed, the permanent Concrete Fascia Wall shall be installed. The permanent concrete facia wall shall be completed within 30 working days of the completion of nail placement.

WORKING DRAWINGS:

Prior to precast concrete fascia installation the Contractor shall verify wall geometry. Geometry shall be provided to the Precast Panel Supplier for development of shop drawings. The Contractor shall then submit to the Engineer the Precast Panel Supplier's details and procedures for Panel, Coping, and CIP closure wall connections for approval by the Engineer.



TYPICAL SECTION THROUGH WALL
SEE LAYOUT FOR SPECIFIC NAIL LOCATIONS



DETAIL A

NAIL REINFORCEMENT LENGTH WILL BE THE LENGTH SHOWN IN THE SOIL NAIL LAYOUT SHEETS PLUS 6 INCHES.

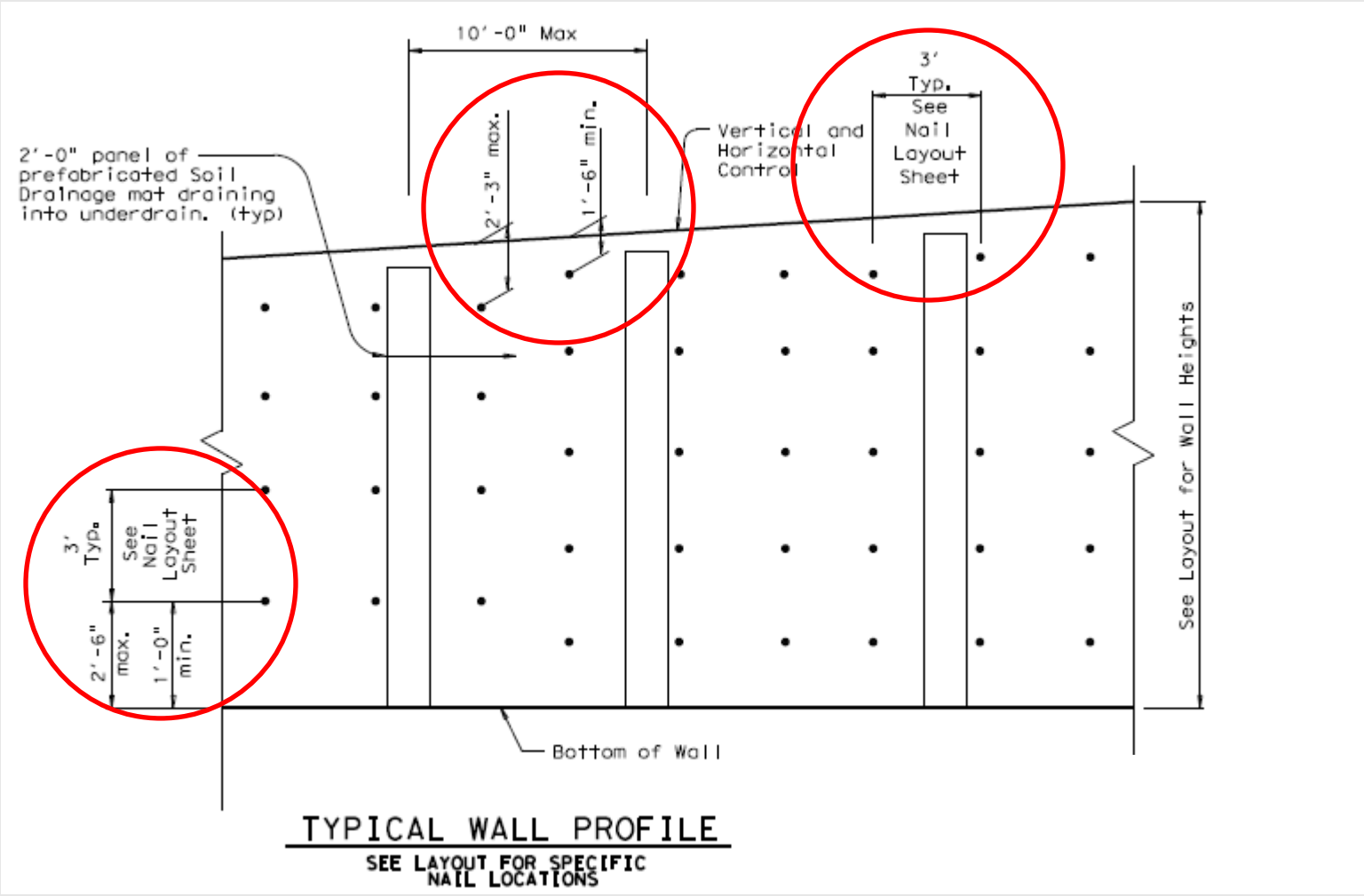
Texas Department of Transportation
Bridge Division

SOIL NAIL RETAINING WALL DETAILS

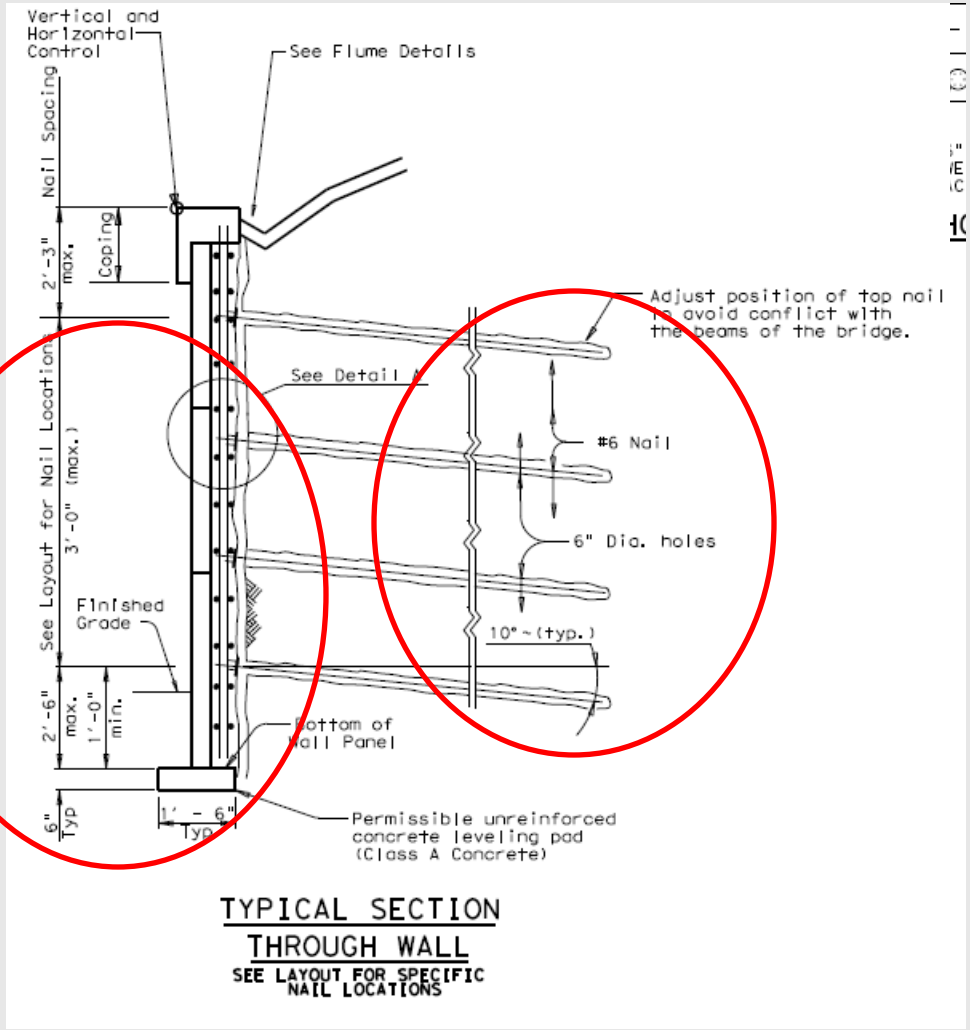
1 of 2

WALL DETAILS A.DGN	DN:	CK:	DW:	CK:
©TxDOT MAY 2013	DISTRICT	PROJECT NUMBER		SHEET
REVISIONS	BRYAN	C 50-3-90		139
	COUNTY	CONTROL	SECT	JOB	HIGHWAY
	GRIMES	0050	03	090	SH 6

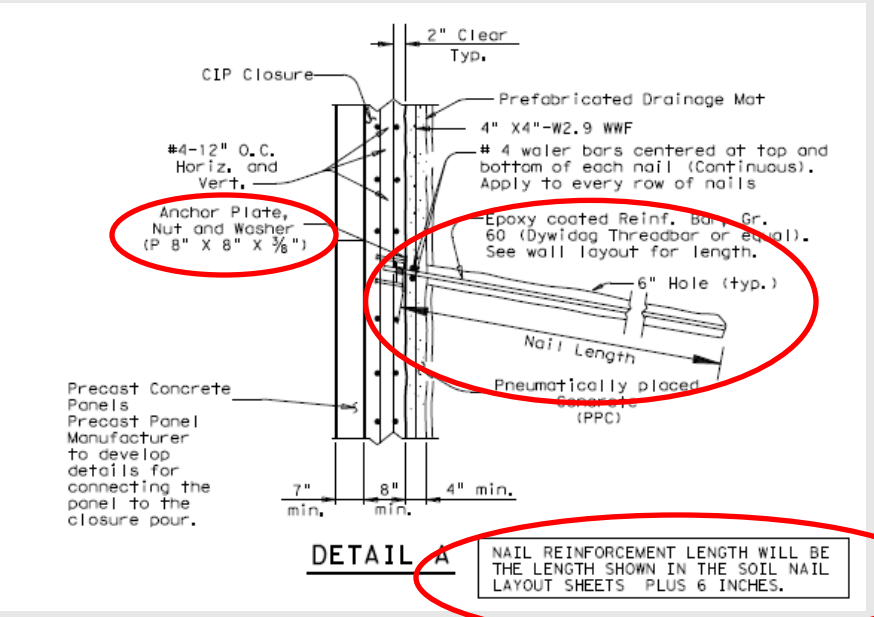
SOIL NAIL DETAIL SHEET

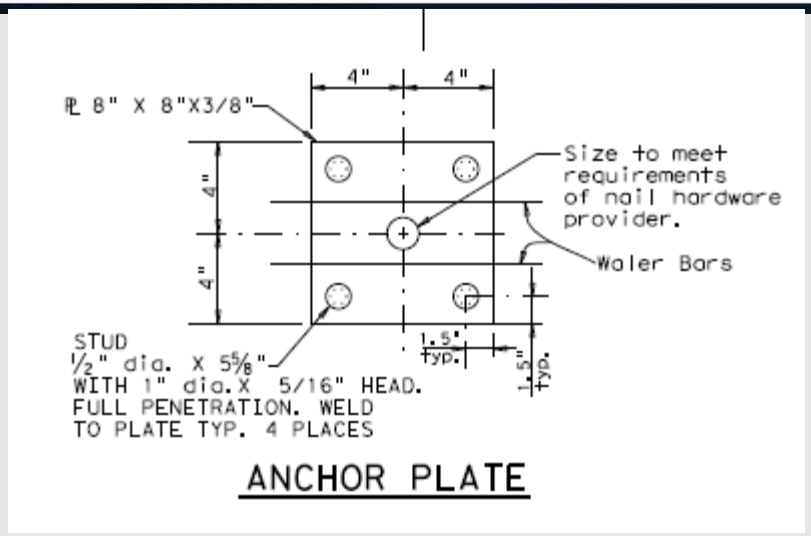


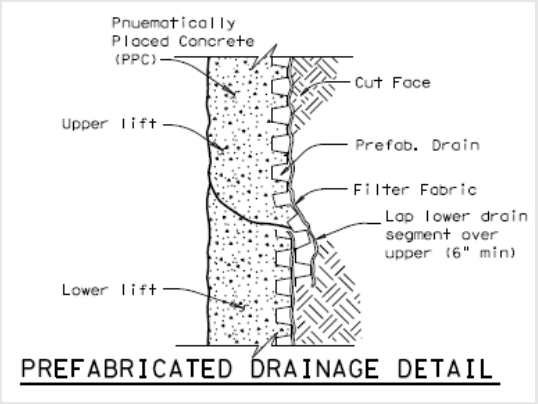
SOIL NAIL DETAIL SHEET



SOIL NAIL DETAIL SHEET



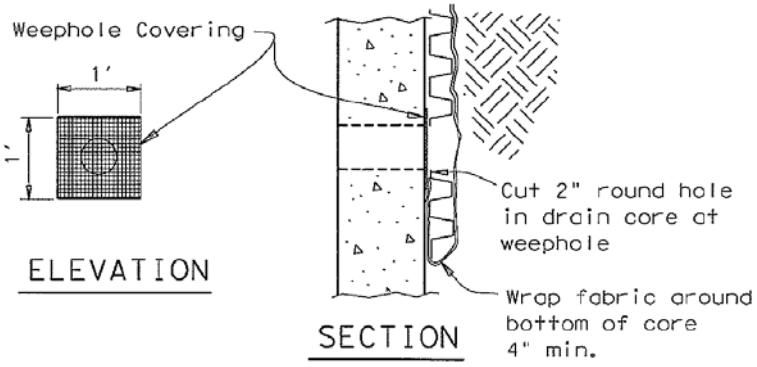


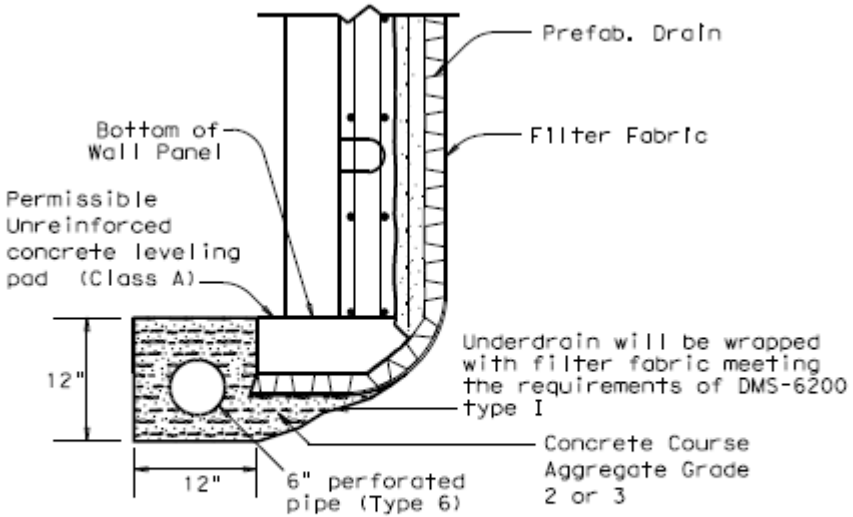


SOIL NAIL DETAIL SHEET

DRAINAGE DETAILS

Weephole Detail

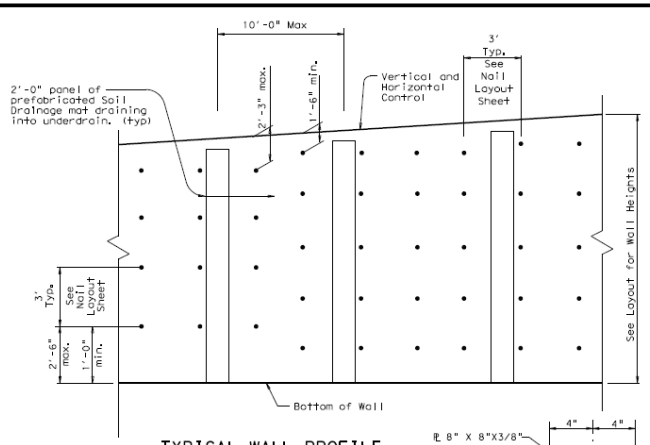




UNDERDRAIN DETAIL

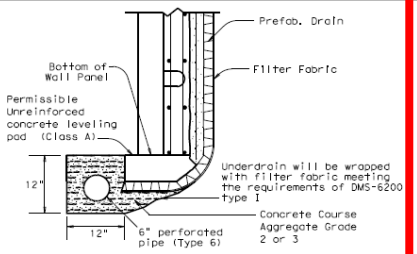
(The location of the underdrain outfall will be determined by the Engineer)

SOIL NAIL DETAIL SHEET



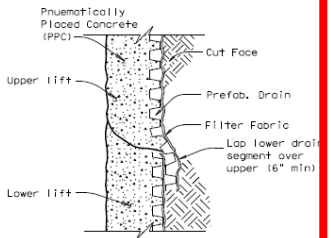
TYPICAL WALL PROFILE

SEE LAYOUT FOR SPECIFIC NAIL LOCATIONS

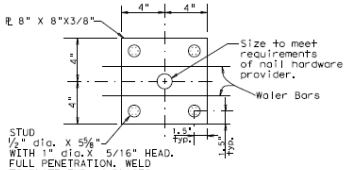


UNDERDRAIN DETAIL

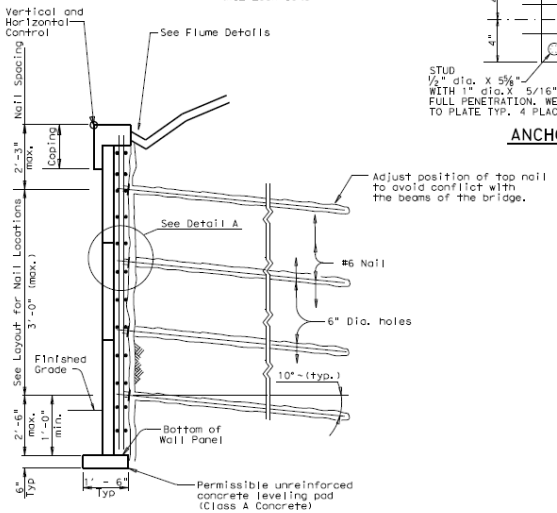
(The location of the underdrain outfall will be determined by the Engineer)



PREFABRICATED DRAINAGE DETAIL

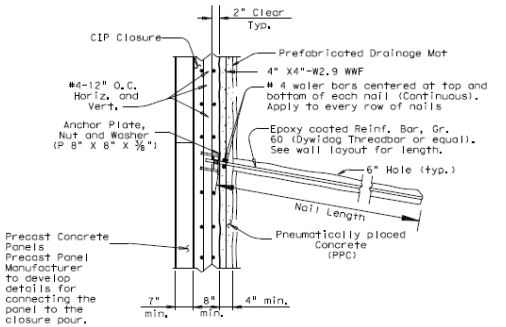


ANCHOR PLATE



TYPICAL SECTION THROUGH WALL

SEE LAYOUT FOR SPECIFIC NAIL LOCATIONS



DETAIL A

NAIL REINFORCEMENT LENGTH WILL BE THE LENGTH SHOWN IN THE SOIL NAIL LAYOUT SHEETS PLUS 6 INCHES.

GENERAL NOTES:

All Concrete shall be Class "C" unless otherwise noted.
All reinforcing steel shall be Grade 60.
Chamfer all exposed corners ¾".
Test nails will be required for each wall. Nail testing shall be in accordance with the requirements shown on this sheet, and in the Soil Nail Anchor Specifications. If widely varying soil conditions are encountered the Engineer may require additional test nail anchors. Test anchors will not be paid for directly but will be considered subsidiary to the item "Retaining Walls" and can not be used as production nails.
Pneumatically placed concrete shall comply with requirements of the item "Pneumatically Placed Concrete" (Class III), except that it will not be paid for directly and strength testing will not be required. Membrane curing will be allowed in place of water curing.
Drainage system shall consist of 2'-0" panels of Prefabricated Soil Drainage Mats emptying into an underdrain. Filter Fabric shall meet the requirements of DMS-6200. Pneumatically placed concrete shall be placed over the drains, with the Drainage Mats placed against the soil. The underdrain outfall shall be as directed by the engineer. The drainage system will not be paid for directly but will be considered subsidiary to the item "Retaining Walls."
The price bid per square foot of Retaining Wall (Facia) shall include all concrete, reinforcing steel, pneumatically placed concrete, precast panels, drainage material, flowable fill, cement stabilized backfill, underdrain and any other materials necessary to complete the wall.
The price bid per linear foot of Soil Nail shall include all drilling, nail reinforcement, grout, and test nails.

NAIL TESTING NOTES:

Testing to be coordinated with TxDOT a minimum of one week prior to the desired testing date. TxDOT personnel will be present during testing, and may choose to monitor the applied test load using their own equipment.
Project test anchors from the face of the cut enough to accommodate the Contractor's loading and measurement devices, as well as an additional 1 ft for the Department's load cell.
Perform testing as specified in the SS "Soil Nail Anchors"to the maximum test load stated.
The location of the test nails will be approved by the Engineer. If widely varying soil conditions are encountered, the Engineer may require additional test nails.
Proof testing will be done in accordance with Special Provision 4116-001, "Soil Nail Anchors".

CONSTRUCTION PROCEDURE:

The slope in front of the retaining wall shall be removed in lifts. The depth of each lift shall be limited to the amount necessary to install a single horizontal row of Soil Nails. At no time shall more than 5'-0" of un nailed vertical cut be exposed. The length of each lift removed shall be limited to the amount that can be nailed in one day. At no time shall any un nailed cut face be exposed for over 48 hours.
Upon completion of each day's installation of nails, pneumatically placed concrete shall be applied to the cut face. The concrete shall be reinforced with a single layer of Welded Wire Reinforcing Fabric, 4" X 4" - W2.9, and #4 waler bars as shown. Anchor Plate, beveled washer, and nuts shall be tightened up to the face of the PPC.
When all rows of nails have been placed, the permanent Concrete Fascia Wall shall be installed. The permanent concrete facia wall shall be completed within 30 working days of the completion of nail placement.

WORKING DRAWINGS:

Prior to precast concrete fascia installation the Contractor shall verify wall geometry. Geometry shall be provided to the Precast Panel Supplier for development of shop drawings. The Contractor shall then submit to the Engineer the Precast Panel Supplier's details and procedures for Panel, Coping, and CIP closure wall connections for approval by the Engineer.

Texas Department of Transportation
Bridge Division

SOIL NAIL RETAINING WALL DETAILS

1 of 2

WALL DETAILS A.DGN	DW:	CK:	DW:	CK:	
© TxDOT MAY 2013	DISTRICT	PROJECT NUMBER			SHEET
REVISIONS	BRYAN	C 50-3-90			139
	COUNTY	CONTROL	SECT	JOB	HIGHWAY
	GRIMES	0050	03	090	SH 6

Make sure to update the General Notes to be consistent with Item 410 “Soil Nail Anchors”

SOIL NAIL DETAIL SHEET

CONSTRUCTION PROCEDURE:

The slope in front of the retaining wall shall be removed in lifts. The depth of each lift shall be limited to the amount necessary to install a single horizontal row of Soil Nails. At no time shall more than 4'-0" of un nailed vertical cut be exposed. The length of each lift removed shall be limited to the amount that can be nailed in one day. At no time shall any un-nailed cut face be exposed for over 24 hours.

Upon completion of each day's installation of nails, pneumatically placed concrete shall be applied to the cut face. The concrete shall be reinforced with a single layer of Welded Wire Reinforcing Fabric, 4" X 4" - W2.9. and #4 waler bars as shown. Anchor Plate, beveled washer, and nuts shall be tightened up to the face of the PPC.

When all rows of nails have been placed, the permanent Concrete Fascia Wall shall be installed The permanent concrete fascia wall shall be completed within 30 working days of the completion of nail placement.

The items in RED need to match the soil conditions and job

WHAT TYPES OF FACING OPTIONS ARE AVAILABLE?

Cast in-place

Precast Panels

Sculpted Shotcrete

SOIL NAIL WALLS DEPEND UPON A PROPER DESIGN AND DETAILS DEVELOPED FOR THE SITE SPECIFIC SOIL CONDITIONS AND GEOMETRY

QUESTIONS?