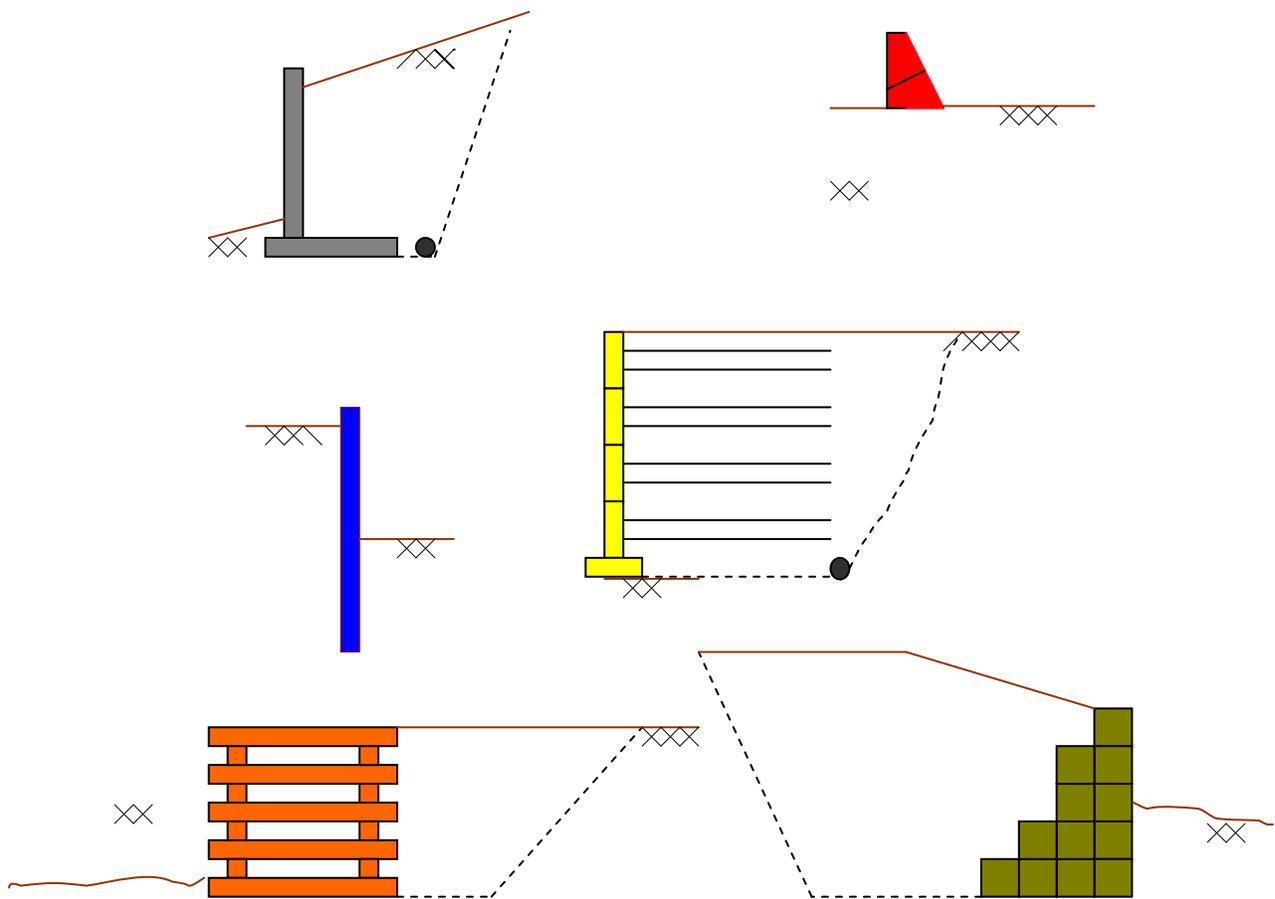


Tennessee Department of Transportation Earth Retaining Structures Manual



Second Edition (version 2.1)
Revised February 3, 2012

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**TENNESSEE DEPARTMENT OF TRANSPORTATION
EARTH RETAINING STRUCTURES MANUAL**

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Chapter I

General Policy

1.0 Introduction

1.1 Objectives

The objectives of this policy are to obtain statewide uniformity, establish standard procedures and delineate responsibility for the preparation and review of plans, design and construction control of earth retaining structures. In addition, it is the intent of this policy to initiate a process for review and approval for both permanent and critical temporary proprietary wall systems so that a list of approved wall systems can be established. A critical temporary wall is one that is necessary to maintain the safety of the traveling public or structural integrity of nearby structures and utilities for the duration of the construction contract.

1.2 Department Division Responsibilities

The following outlines the organizational unit and necessary actions by that unit to select, coordinate and review designs and monitor construction.

A) Design Division

- 1) Determine the need for earth retaining structures. If the retaining structure is located in the 30 foot clear zone or high hazard locations as determined by the Safety Planning & Traffic Office, wall protection may be required and the note in section 3.2(M) shall be placed on the conceptual drawings for the proposed retaining wall.
- 2) Initiate and prepare plans in accordance with section 3.0 Concept Drawing Preparation on pages I-3 and I-4 of this policy.
- 3) Submit roadway plans with initial concept drawings as developed above to the Utilities Section, Hydraulic Section, and Materials and Tests Division as deemed appropriate. Submit using the standard transmittal letter shown in Appendix C.

B) Materials and Tests Division

- 1) Perform subsurface investigation, laboratory analysis/testing and prepares foundation report for the earth retaining structures.
- 2) Recommend suitable walls from an approved list

- 3) Add appropriate information to conceptual plans in accordance with section 3.0 and forward to Structures Division.
- 4) Geotechnical review of wall proposal submitted by the Contractor.
- 5) Inspect site of construction during crucial phases as determined by their staff.
- 6) Assist the Construction Division during any phase of construction upon request.
- 7) Keep retaining wall inventory records.
- 8) Assist the Division of Structures in upgrading design procedures and construction procedures.
- 9) Keep record of approved list of retaining wall systems, material specifications, electronic copies of the design drawings and detail design computations.
- 10) Keep up-to-date record of the *Tennessee Department of Transportation Earth Retaining Structures Manual* and make proper distribution of all changes.
- 11) Determine if system is to be monitored. If so, administer a monitoring plan during and after the earth retaining system has been constructed.

C) Structures Division

- 1) Determine if bridge sites merit the use of an earth retaining structure from an economic comparison of alternatives. If so, develop and submit concept plans to the Design Division and Materials and Tests Division.
- 2) Evaluate list of recommended walls submitted by the Materials and Tests Division, then select the alternates most economically and aesthetically suited for project.
- 3) Finalize conceptual plans and cost estimates in accordance with section 3.0 then submit to the Construction Division for contract letting. *Note: Square foot pay limits for walls to be shown on plans.*
- 4) If federally funded interstate project, submit final plans to FHWA for review.
- 5) After receiving the proposed retaining wall plans from the Contractor, submit a copy of the plans to the Materials and Tests Division for

concurrent review. Upon reviewing comments per Division of Materials and Tests, notify the Contractor as to the approval of their proposal.

- 6) Inspect site during crucial construction phases.
- 7) Assist the Construction Division during any phase of construction.
- 8) Upgrade design procedures and construction specifications.

D) Construction Division

- 1) Review Retaining Wall Conceptual sheet prior to wall construction to become familiar with construction requirements.
- 2) Obtain and distribute for review Contractor's wall design plans and calculations.
- 3) Inspect wall construction activities to assure compliance with construction and materials specification requirements.
- 4) Relay any design or construction related problems to appropriate parties for resolution.

2.0 Wall Selection Procedure

The decision to select a particular retaining wall system for a specific project requires a determination of both technical feasibility and comparative economy. With respect to economy, the factors that should be considered are:

- A) cut or fill earthwork situation
- B) size of wall area
- C) average wall height
- D) foundation conditions (i.e. would a deep or shallow foundation be appropriate for a cast-in-place concrete retaining wall)
- E) availability and cost of select backfill material
- F) cost and availability of right of way needed
- G) complicated horizontal and vertical alignment changes
- H) need for temporary excavation support systems

- I) maintenance of traffic during construction
- J) aesthetics

The Department should consider all feasible alternates and provide at least two (2) alternates whenever possible. (See Tables 1 & 2 on pages II-18 and II-19 in Chapter II for advantages and disadvantages associated with various wall types.) The wall types listed as Acceptable Wall Types as required under Section 3.1 are those wall types determined by the Department to be technically, economically and constructability-wise feasible. Except as allowed for in Section 4.8 the contractor must bid on, have designed and construct the wall type(s) shown in the plans. If the Department provides a specific wall design with details the contractor must provide a bid for and be prepared to construct the wall as provided for in the plans.

3.0 Concept Drawing Preparation

Projects containing earth retaining structures shall use a concept drawing approach: a fully detailed set of retaining wall plans will not be contained in the bidding documents. Under special circumstances the Department may choose to design and prepare detailed plans for a specific wall. The concept drawing, furnished by the Department in the bidding documents will contain the following geometric and design project specific information:

- 3.1 List of acceptable wall types and/or systems for each wall on the project. The Geotechnical Section of the Division of Materials and Tests will provide recommendations for all those wall types that are geotechnically feasible. The Structures and Design Division will determine if wall types would be further limited due to structural, design or aesthetic requirements.
- 3.2 Geometrics
 - A) Beginning and end of wall stations (*Design)
 - B) Elevations on top of wall at beginning and end of wall station as well as all break points (*Design)
 - C) Original and proposed ground line profiles in front of and behind the retaining wall (*Design)
 - D) Cross sections at the retaining wall locations at intervals as determined by the Department (*Design)
 - E) Horizontal wall alignment (*Design)

- F) Details of wall appurtenances such as traffic barriers, coping, fencing, drainage, location and configurations of signs and lighting including conduit locations and right-of-way limits (*Design)
- G) Construction sequence requirements if applicable, including traffic control, access, and stage construction sequences (*Design)
- H) ROW Limits and cross sections shall be shown on the retaining wall conceptual drawing. Elevation of highest permissible level for foundation construction (Structures, *Design, Materials and Tests Division)
- I) Location, depth and extent of any unsuitable material to be removed and replaced. Details of any required ground improvement (Materials and Test)
- J) Quantities table showing estimated wall area and quantity of appurtenances and traffic barriers (Structures)
- K) At abutments, elevations of bearing pads, location of bridge seats, skew angle and all horizontal and vertical survey control data including clearance and details of abutments (Structures)
- L) At stream locations, extreme high water, normal water levels and estimated scour depth (Structures)
- M) If required, Design Division places the following note on the conceptual drawings concerning protection against vehicular impact (*Design):

NOTE: Proposed Retaining wall is located in an area that is susceptible to vehicular impact. See Tennessee Department of Transportation Earth Retaining Structures Manual for the minimum structural requirements that shall be met by the wall system to provide protection from impact. Wall Systems not meeting the requirements shall have a 51 inch tall barrier rail placed directly in front of the wall with all cost of the barrier wall and end treatments (S-GR-24) included in the square foot cost of the proposed retaining wall.

- * Denotes Structures Division will be responsible if their office initiates use of a wall system at a bridge site.

3.3 Geotechnical Information (Materials and Test)

A copy of the subsurface investigation report and specific design values for the following parameters (where required):

- A) Shear strength (drained and undrained for fine grained soils) of foundation soils

- B) Allowable bearing pressure and consolidation properties for foundation soils
- C) Required shear strength and unit weight ranges of select backfill
- D) Shear strength of random fill or in-situ soil behind wall

3.4 General Structural and Geotechnical Design Requirements

The following are general design requirements for retaining walls that will be shown on the concept drawings or addressed in the contract documents. Specific design requirements for each of the wall types are provided in Chapter III.

- A) Design life of the structure (example: permanent mechanically stabilized earth walls are commonly designed, based on corrosion, for minimum service lives of 75 years). (Structures)
- B) Minimum safety factors for overturning, sliding and stability of temporary construction slopes. (Typical values are overturning 2.0, sliding 1.5, and temporary construction slopes 1.2). **An analysis for overall external slope stability will be performed by the Materials and Tests Division.** (Materials and Test)
- C) Allowable foundation bearing pressure, minimum wall footing embedment depth and maximum tolerable total and differential settlements. (Materials and Test. Note: Driven piles are to support Cast-in-Place Concrete Gravity and Cantilever walls only. Pile driving will not be an acceptable method of improving the allowable bearing pressure of the MSE type wall foundations))
- D) Internal design requirements for mechanically stabilized earth wall products, to include allowable reinforcement material stress (typically 0.55 FY for steel), safety factor against reinforcement pullout (typically 1.5) and allowable lateral deformation for the interpretation of laboratory pullout tests (typically $\frac{3}{4}$ "). Also include allowable stresses as discussed in AASHTO *Standard Specifications For Highway Bridges* Division 1, Section 5, for tiebacks, inextensible and extensible reinforcement and soil nails when appropriate. (Materials and Test)
- E) Magnitude, location and direction of external loads due to bridges, overhead signs and lights, traffic surcharge and rapid groundwater draw down. (*Design)
- F) Limits and requirements for drainage features beneath, behind, or through the retaining structure. (*Design)

- G) Backfill requirements for both within and behind the retaining structure (Materials and Test)
- H) Special facing panel and module finishes or colors. (Structures)
- D) Governing sections of construction specifications and specifications within this manual. (Design, Materials and Test and Structures)

The preparation of the concept plan is a coordinated activity between the Design Division, Structures Division and the Division of Materials and Tests. Design consultants are responsible for submitting retaining wall recommendations to the Department for review and action. Geometric, geotechnical and structural considerations must be complementary for the conceptual plan to convey the desired end product to the bidders.

4.0 Requirements for Contractor/Supplier Prepared Design Plans

The Contractor shall utilize the information contained on the Retaining Wall Conceptual drawing as well as information shown elsewhere in the plans to prepare his bid for the wall during the project bidding process and to prepare wall design plans during the construction of the project. The final design shall be submitted subsequent to contract award and a minimum of sixty (60) days prior to wall construction and shall include detailed design computations and all details, dimensions, quantities and cross sections necessary to construct the wall. Acceptable wall types will be identified on the concept drawing. Specific wall systems will typically be selected from the approved list in affect at time of bid letting. See Chapter IV for the approved list. The Contractor shall not bid for nor shall the Contractor submit plans for (except for situations as discussed in Section 4.8) wall types and/or specific wall systems not listed as an Acceptable Wall Type on the Retaining Wall Conceptual Drawing and related drawings.

The plans shall be prepared to include but not be limited to the following items:

4.1 A plan and elevation sheet or sheets for each wall containing the following:

- A) An elevation view of the wall showing grades at the top of the wall, every 50 feet along the wall and at all horizontal and vertical break points. Elevations at the top of leveling pads and footings, the distance along the face of the wall to all steps in the footings, and leveling pads, the designation as to the type of panel or module, the length, size and number of tiebacks, nails, mesh or strips and all the distances along the face of the wall to where changes in length of the reinforcing elements occur and the location of the original and final ground line should be shown. The Contractor shall be responsible for field verifying original ground elevations.

- B) A plan view of the wall shall indicate the offset from the construction centerline to the face of the wall at all changes in horizontal alignment, the limit of the widest module, tiebacks, nails, mesh or strip and the centerline of any drainage pipe which is behind or passes under or through the wall.
- C) Any general or special notes, standard or special drawings, or other unique provisions required for construction of the wall.
- D) All horizontal and vertical curve data affecting wall construction.
- E) Cross sections showing limits of construction and in fill sections, limits and extent of select granular backfill material placed above original ground.
- F) Limits and extent of reinforced soil volume.

4.2 Details

- A) All structural details including reinforcing bar bending details. Bar bending details shall be in accordance with CRSI standards.
- B) All details for foundations and leveling pads, including details for steps in the footings or leveling pads, as well as allowable and actual maximum bearing pressures.
- C) All modules and facing elements shall be detailed. The details shall show all dimensions necessary to construct the elements, all reinforcing steel in the element, and the location of reinforcement element attachment devices embedded in the facing.
- D) All details for construction of the wall around drainage facilities, overhead sign footings and abutment piles shall be clearly shown.
- E) All details for connections to traffic barriers, coping, parapets, noise walls and attached lighting shall be shown.
- F) All details for drainage behind wall or reinforced soil volume.
- G) If vehicular impact protection is required due to the wall system not satisfying the minimal design requirements of Section 5.0, details of the barrier wall and end terminals shall be shown on the Contractor/Supplier Design plans for the proposed wall.

4.3 Detailed design computations which clearly demonstrate compliance with design requirements provided in this manual.

4.4 Limits of design responsibility, if any.

- 4.5 Each design submittal shall include a detailed list of quantities for each wall unit. The quantities shall include but not be limited to: concrete cast in-place, pre-cast concrete, select backfill material, backfill material, reinforcing steel, geomembrane/geogrid reinforcement, modular blocks, structural steel, prestressing steel, etc... If known, all materials sources shall be identified so acceptance and verification sampling and testing can be conducted. All quantities listed are for informational purposes only. All retaining walls shall only be paid for under the respective retaining wall bid item measured as described herein.
- 4.5 The plans shall be signed, stamped and dated by a qualified registered Professional Engineer licensed in the State of Tennessee.

4.7 Submittals and Approval

Four sets of design drawings and detail design computations shall be submitted to the Structures Division. The computations shall include a detailed explanation of any symbols and computer programs used in the design of walls. All designs and construction details will be checked by the Structures Division and the Materials and Tests Division against the pre-approved design drawings and procedures for that particular system. (Structures Division will submit two of their four copies to the Division of Materials and Tests.) Each design drawing shall contain in the title block the project number, county, structure name, structure number, station and contract number. Design drawings shall be submitted in sets with the drawing numbers running consecutively in each set, and if more than five (5) sheets in a set, shall be appropriately bound. Approval of the detailed design and plans shall be made by the Structures Division and Materials and Tests Division. Notification to proceed shall be made by the Structures Division. After approval, the Contractor shall submit additional sets of the design drawings (full size and half size) as determined by the Structures Division for Departmental distribution. Also, an electronic copy of the design drawings and detail design computations shall be submitted to the Materials and Tests Division upon completion of the project. For detailing conventions, see Appendix B.

4.8 Other Submission Requirements

As discussed in the previous sections, the Contractor shall bid for and, subsequently, (for the Contractor for which the project was awarded) prepare plans for and be prepared to construct the wall type(s) given on the Retaining Wall Conceptual Drawing or, under special circumstances, the specific wall type as provided by in the Contract Plans. The Contractor awarded the project may only under the circumstances discussed below request that a wall type, wall system, or associated construction for a wall (i.e., foundation improvement requirements, construction sequence requirements, etc.) be changed, altered, or eliminated from those requirements set forth in the plans.

The Contractor may request the Department consider a change in the wall type, specific system, and associated construction through the submission of a Value Engineering Change Proposal (VECP) unless the contract prohibits submission of a VECP. Furthermore, any conditions of a VECP, such as a minimum cost savings required by the contract must be followed. The Department's agreement to review a VECP for a retaining wall shall in no way imply subsequent acceptance of the VECP or any part thereof. Any costs associated with preparation and submittal of a VECP shall be borne by the Contractor and no construction scheduling changes or time delays shall be caused by the Contractor's submission of the VECP and the Department's review of the VECP. If the proposed change involves a wall system not on the Approved Wall System list then the contractor must coordinate with the system supplier to gain approval of the system in accordance with Section 6.0 and shall be aware of the time considerations for this approval process.

The Contractor may request the Department consider a change in the wall type, specific system, and/or associated construction if the Contractor determines that project conditions exist that may differ from those conditions upon which the decision to specify in the plans a particular wall type(s), wall system, or associated construction was made. An example of this would be where a soldier pile-lagging wall is specified as the only wall type due to right-of-constraints not allowing for a typical wall type to be built, then subsequently it is determined TDOT can acquire or has enough right-of-way available to make another wall type feasible

The request for consideration of changing of a wall type, system, or associated construction shall be made in writing using the format shown in Appendix D and be submitted to the Construction Engineer. **The Construction Engineer will distribute the request to the Regional Construction Engineer, Structures Division, Geotechnical Engineering Section, Design Division, and Right-of-Way Division, if applicable.** The parties will review the request and provide recommended action (approval, rejection, alterations) to the Construction Engineer. If necessary, a plans revision will be made. Note that the Contractor's submission of a request does not imply acceptance by the Department and that the request process shall not be justification for a project schedule change or time extension. The Department reserves the right to require the Contractor to construct the wall as shown in the plans if a condition does not exist that renders the contract plan wall not constructible.

The Contractor must provide documentation in the request to demonstrate that the proposed change does not in any way cause additional cost to the wall and associated construction or to other aspects of the project. If the Contractor judges that a change involving wall construction must be made due to differing site conditions, the Contractor must follow procedures given in Sections 104.02 and 104.03 of TDOT Standard Specifications for Road and bridge Construction.

5.0 Requirements for retaining wall protection provided by the retaining wall system

When noted on the plans that a retaining wall is located in a hazard zone subject to vehicular impact, the Contractor shall be aware that retaining wall protection against vehicular collision for the wall may be required. If the retaining wall facing meets any **one** of the following criteria, an independent barrier wall shall be provided in front of the wall and included in the square cost of the wall:

- 1) Any retaining wall facing that is constructed of non-reinforced concrete (cast-in-place concrete gravity walls are exempt from this requirement and do not require protection.
- 2) Any dimension of a retaining wall facial panel that is less than 5'0" x 5'0" x 6" thick reinforced panel.
- 3) Any type of crib retaining walls.
- 4) A cast in place reinforced facing that has a thickness less than 6 inches.

6.0 Materials Approval

Prior to delivery of any material used in the retaining wall construction, the sources must be accepted in conformance with the material specifications associated with the wall type being constructed.

7.0 Initial System Approval

7.1 Supplier Submittals

A proprietor or contractor interested in having a system approved by the Tennessee Department of Transportation shall submit a written request to the Structures Division Director (Tennessee Department of Transportation at the James K. Polk State Office Building, Suite 1100, 505 Deaderick Street, Nashville TN 37243-0349). The Division of Structures will contact the Materials and Tests Division to jointly decide if a formal presentation describing the system and its applications is necessary. If necessary, this presentation will be given at the Department's convenience. Prior to the presentation, the proprietor/contractor will provide the Structures Division with two (2) copies of the *Technical Evaluation Report* for the evaluation of the specific wall system as prepared by the Highway Innovative Technology Evaluation Center (HITEC), a service center of the Civil Engineering Research Foundation (CERF). The Division of Structures will provide one copy of the report to the Division of Materials and Tests. It is expected that the HITEC Report will contain the following information:

- A) System theory and its derivation
- B) Laboratory and field experimentation which support the theory, including case histories of instrumented structures
- C) Practical applications with descriptions and photographs
- D) Limitations and disadvantages of the system. Also, provide case histories of structures where problems have been encountered, including an explanation of the problems and methods of repair
- E) List of users including names, addresses, and phone numbers
- F) Details of wall elements, analysis of structural elements, design calculations, factors of safety, estimated life, corrosion design procedures for soil reinforced elements, procedures for field and laboratory evaluation including instrumentation and special requirements
- G) Sample material and construction control specifications showing material type, quality, certifications, field testing, acceptance and rejection criteria, and placement procedures
- H) A well documented field construction manual describing in detail, and with illustrations where necessary, the step by step construction sequence
- I) Typical unit costs (i.e., per area of wall surface including face of footing), supported by data from actual projects
- J) Complete sets of plans from at least three previously constructed projects
- K) Documentation to support the proprietor's ability to meet production requirements of the various wall components
- L) Standard details showing the following: wall panel-abutment interfacing, slip joints, barriers, panel reinforcements, steps in leveling pad, coping details, and placement of reinforcement elements around obstructions (inlets, utilities, piling, etc)
- M) Provide a listing of maintenance requirements to maintain performance and repair damage. If available, provide a maintenance manual
- N) List any contractor or subcontractor prequalifications

7.2 Department Action

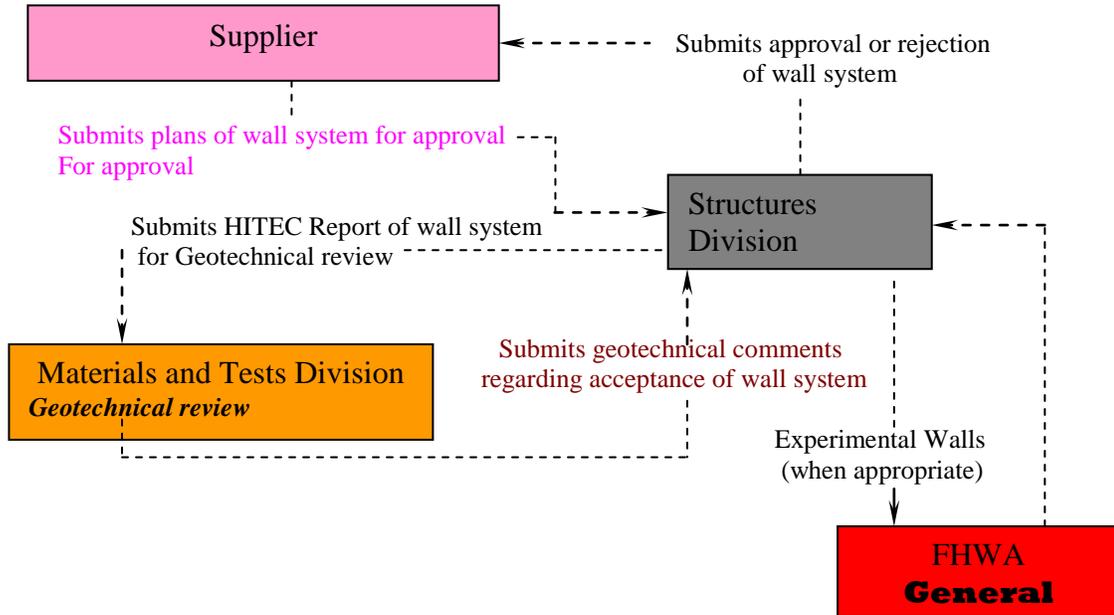
The submission will be reviewed by the Division of Structures and the Division of Materials and Tests. The Department's position on the wall system (i.e., rejection or approval) will be provided to the proprietor/contractor by written notification from the Division of Structures within ninety (90) days after receipt of the submission. Once approval is obtained, the Department may add the product to the approved list or may elect the following course of action:

- A) The Department will select a suitable project for evaluation of the wall system and notify the proprietor/contractor of same. The wall system may be considered temporary or permanent. Wall systems on all Federal Aid Projects will be considered experimental and will have a work plan. Projects with FHWA oversight will have a work plan submitted to FHWA by the Department.
- B) The Department will provide the proprietor/contractor with control plans prepared either in-house or by the consultant Engineer-of Record.
- C) The proprietor/contractor shall submit four (4) complete design plans to the Division of Structures during the design phase as soon as possible after receipt of control plans. (The Division of Structures will provide two of these four design plans to the Materials and Tests Division.) The proprietor/contractor is forewarned that he must comply with scheduling requirements that will not delay letting or construction of the project.
- D) In order to evaluate the performance and constructability of the wall system, a required field and/or laboratory instrumentation program may be developed by the Division of Materials and Tests. These will typically be made part of the contract bid package. The nature and extent of this program will vary significantly with the various wall systems. The system's performance and constructability will be monitored at the discretion of the Department. Monitoring shall be performed by the Department or by an independent pre-qualified engineer provided by the Contractor and approved by the Department. After bid letting and at least sixty (60) days prior to any construction the proprietor/contractor will submit construction plans, material details and specification and construction procedures and design computations for approval prior to shipping any materials to the project.
- E) On completion of the project, the Department will provide a written report to the Federal Highway Administration and the proprietor/contractor. The report will summarize the results of the monitoring program. This will include recommendations for acceptance, rejection, or the need for an additional experimental project with that particular system.
- F) With concurrence from the Department and FHWA, the wall system is added to the Department's approved list. As such, that particular system may then be considered for all suitable future applications as determined by the Department. The Division of Materials and Tests will maintain an approved list for both permanent and critical temporary wall systems.

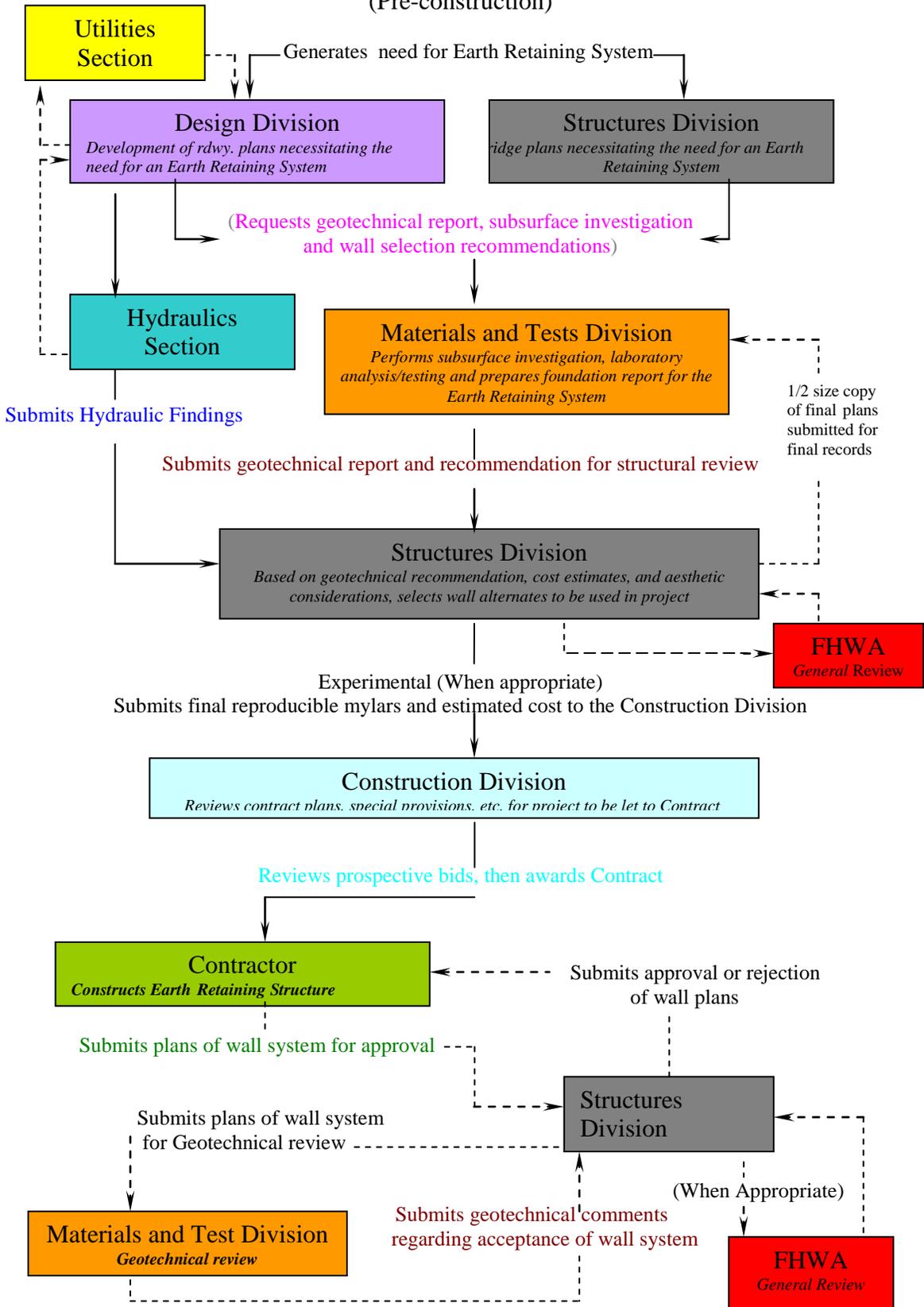
- G) Any changes/modifications to any particular wall system made subsequent to being on the approved list may necessitate a complete or partial re-submission by that proprietor/contractor and a re-evaluation by the Department.

The Department reserves the right to remove a wall system/supplier from the Approved Systems list if , in the opinion of the Department, the wall system is not performing adequately, design and /or construction procedures are not being followed or other reasons that the Department deems justifiable cause for removal from the list. The Department will inform the wall system/supplier of the reasons for removal and will provide a means by which the wall system/supplier can request to be reinstated to the Approved Systems list.

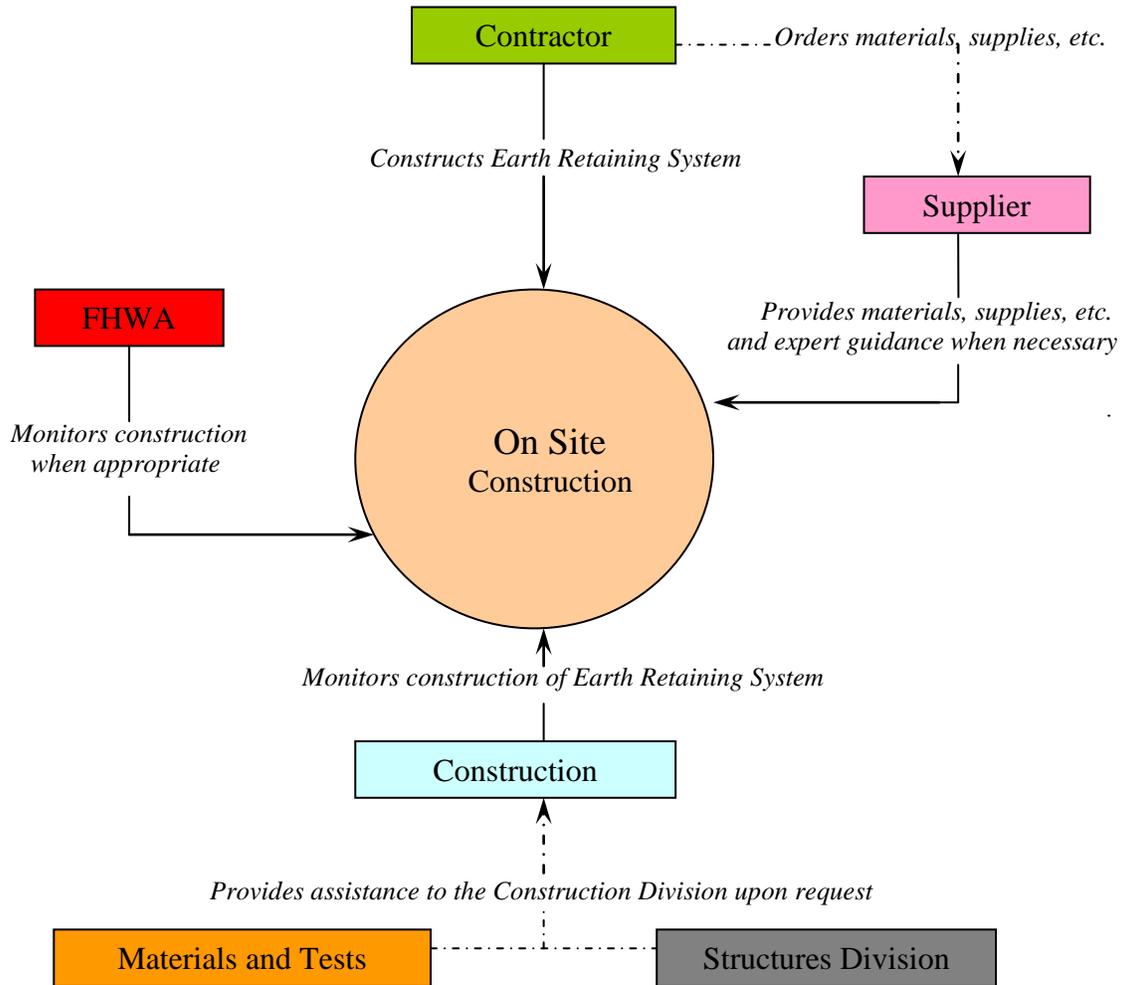
Proposed System Approval (Pre-construction)



Responsibility Flow Chart for Earth Retaining Systems (Pre-construction)



Responsibility Flow Chart for Earth Retaining Systems (Construction Phase)

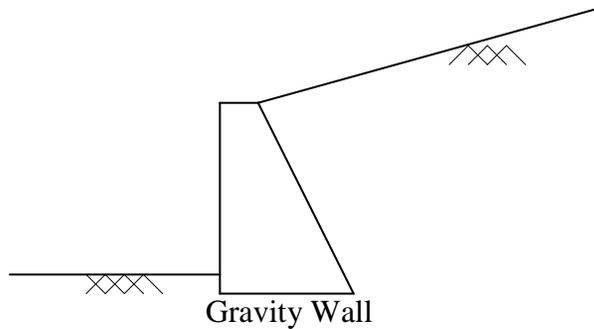


Chapter II

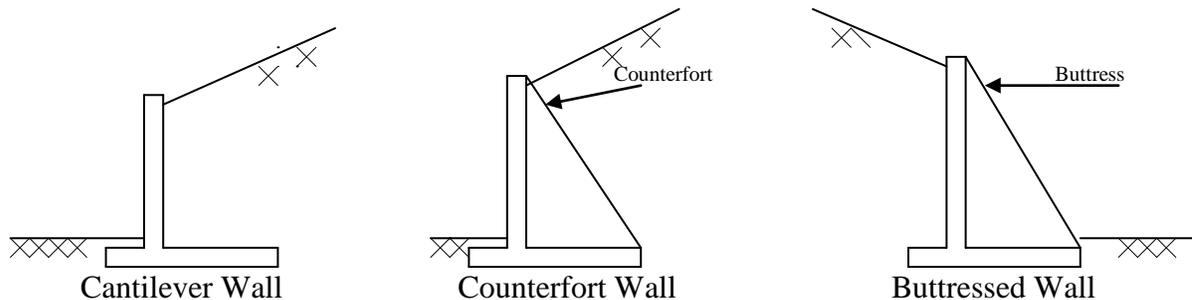
Earth Retaining Systems

I. Fill Walls

- A) **Rigid Cast-In-Place Gravity Wall**- A CIP concrete gravity wall is generally trapezoidal in shape and constructed of mass concrete. The wall relies on self weight to resist overturning and sliding due to the lateral stresses of the retained soil.

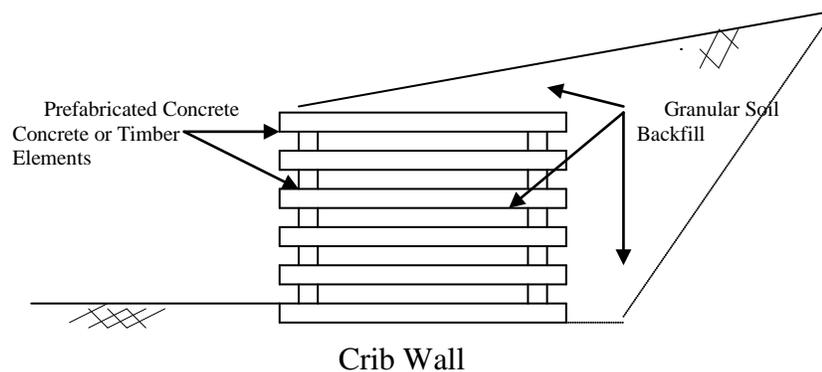


- B) **Cast-In-Place Semi-Gravity Wall**- CIP semi-gravity wall consist of reinforced concrete stem and bases. For counterforts or buttressed walls, vertical reinforced concrete beams are utilized.

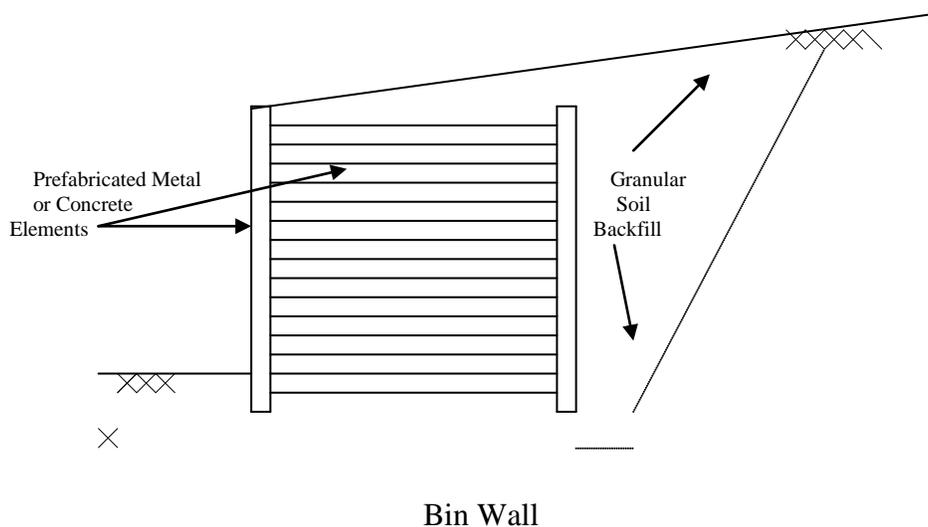


C) Prefabricated Modular Gravity Walls

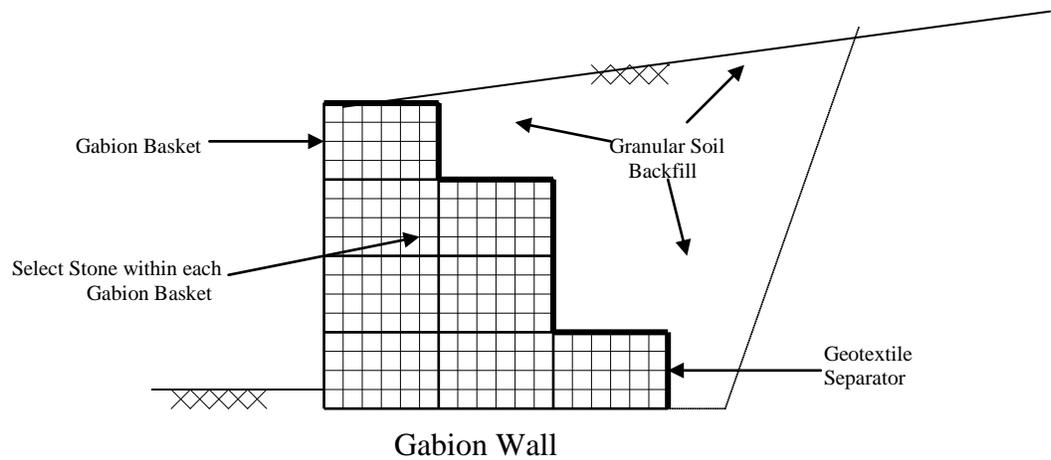
- 1) **Crib Wall**- A concrete crib wall is a gravity retaining structure constructed of interlocking prefabricated reinforced or unreinforced concrete elements. Timber crib walls can be constructed of either stacked “log-cabin style” prefabricated timber elements or stacked timber beams that are nailed together using steel spikes. Each crib is comprised of alternating transverse and longitudinal horizontal beams. Each crib unit is filled with granular, free draining soil, which is compacted inside each unit.



- 2) **Bin Wall**- Concrete and metal bin walls are gravity retaining structures built of adjoining closed-face or open-face bins. Each unit of a metal bin wall is comprised of individual members which are bolted together on-site. Each unit of a concrete bin wall is comprised of interlocking prefabricated reinforced concrete modules that are placed like building blocks.

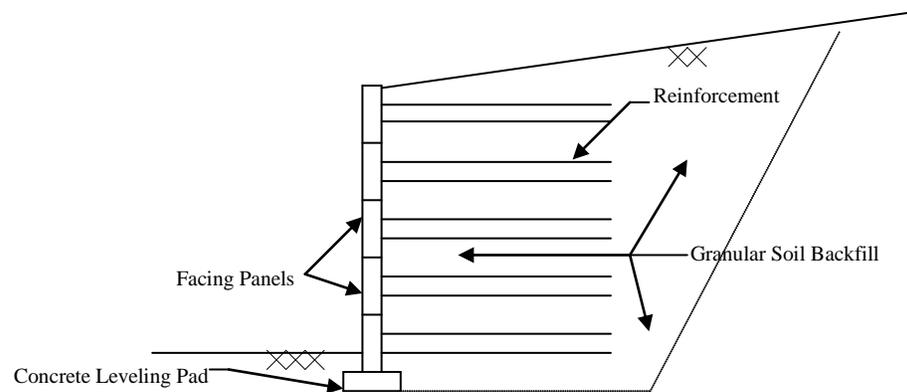


- 3) **Gabion Wall**- Gabion walls are compartmented units filled with stone that are 4” to 8” in size. Each unit is a rectangular basket made of galvanized steel, geosynthetic grid, or polyvinylchloride (PVC) coated wire. Each gabion unit is laced together on-site and filled with select stone. Gabion walls can be designed with wire mesh or geosynthetic reinforcement that extends back into the retained soil from between the gabion unit. These wall systems are termed tailed gabions.



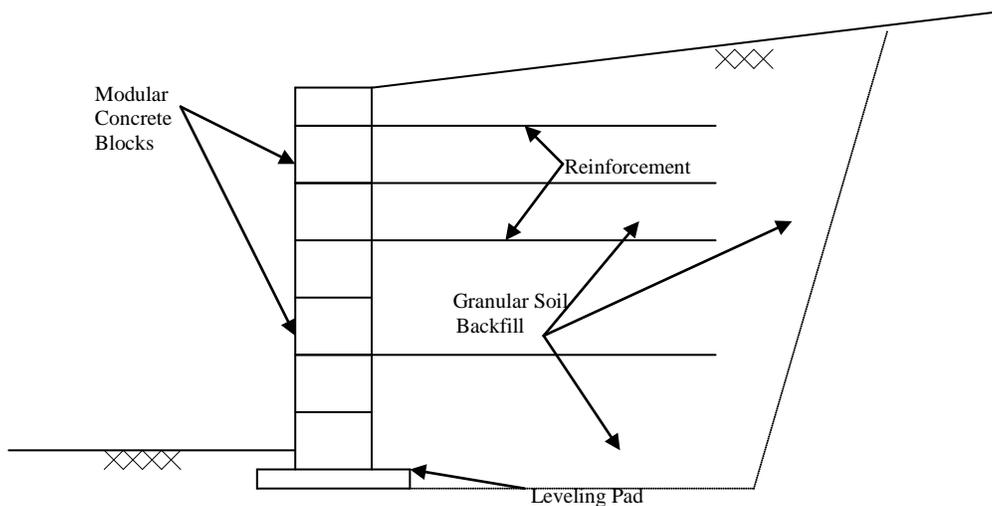
D) Mechanically Stabilized Earth (MSE) Wall

- 1) **Segmental, Precast Facing (Mechanically Stabilized Earth (MSE)) Wall-** A Segmental, precast facing mechanically stabilized earth (MSE) wall employs metallic (strip/bar mat or geogrid or geotextile) reinforcement that is connected to a precast concrete or prefabricated metal facing panel to create a reinforced soil mass. The reinforcement is placed in horizontal layers between successive layers of granular soil backfill. Each layer of backfill consists of one or more compacted lifts. A free draining, nonplastic backfill soil is required to ensure adequate performance of the wall system.



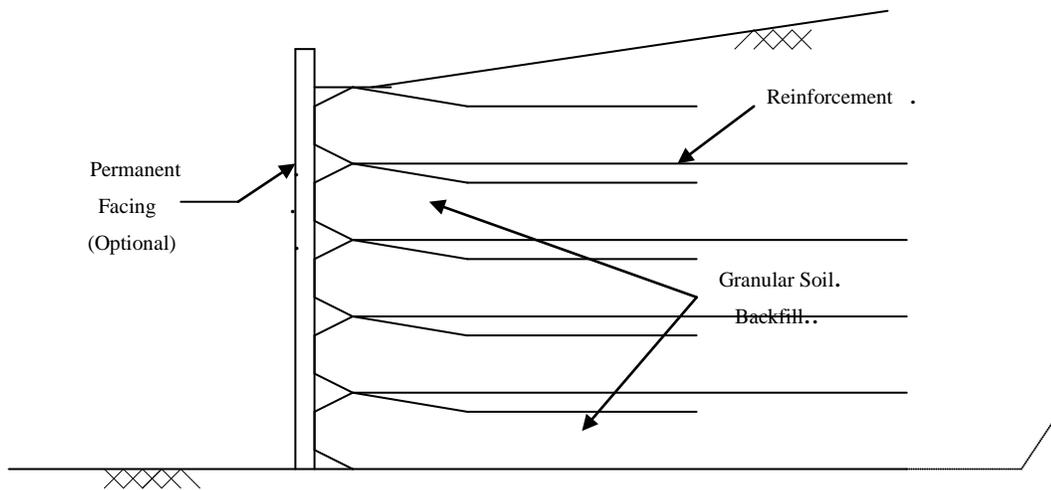
Segmental, Precast Facing Mechanically Stabilized Earth (MSE) Wall

- 2) **Prefabricated Modular Block Facing (Mechanically Stabilized Earth (MSE)) Wall**- A modular concrete block facing wall consists of vertically stacked, dry cast concrete blocks in which geogrid, metallic grid, or geotextile reinforcement is secured between the blocks at predetermined levels. The reinforcement extends from the blocks into a granular soil backfill. Each layer of the backfill consists of one or more compacted lifts. The reinforcement may be connected to the wall face through friction developed between vertically adjacent blocks or through the use of special connectors. The concrete blocks may be solid or have a hollow core. Hollow core blocks are filled with crushed stone or sand during construction.



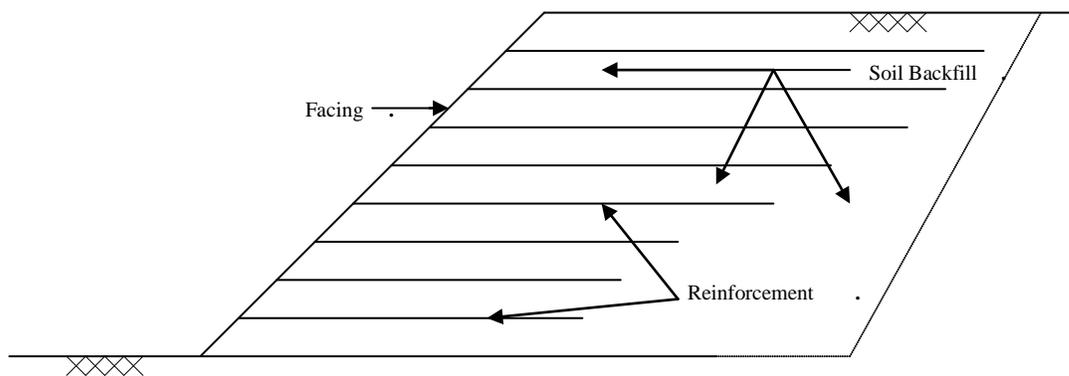
Prefabricated Modular Block Facing
Mechanically Stabilized Earth (MSE) Wall

- 3) **Geotextile/Geogrid/Welded Wire Facing (Mechanically Stabilized Earth (MSE)) Wall**- These wall systems consist of continuous or semi-continuous layers of geotextile, geogrid, or welded wire mesh laid down alternately with horizontal layers of compacted soil backfill. The wall facing is constructed by wrapping each layer of reinforcement around the overlying layer of backfill and then reembedding the free end into the backfill. Each layer of backfill consists of one or more compacted lifts. Permanent facings include shotcrete, gunite, galvanized welded-wire mesh, or prefabricated concrete or wood panels.



Geotextile/Geogrid/Welded Wire Facing
Mechanically Stabilized Earth (MSE) Wall

- C) **Reinforced Soil Slope (RSS) Wall, (Internally Stabilized Fill Wall)**- These earth retaining systems incorporate planar reinforcement, typically geotextile or geogrid, in constructed earth slopes with face inclinations of less than 70 degrees. The reinforcement is laid down alternately with horizontal layers of compacted soil backfill. Each layer of backfill consists of one or more compacted lifts. If slope facing is used to prevent erosion or provide a desired appearance, the facing may be constructed by: (1) extending reinforcement layers outside the slope face and wrapping each layer around the overlying backfill and then reembedding the free end into the backfill; or (2) extending reinforcement to slope face and then either vegetating the face, or placing erosion control mats or prefabricated elements against the slope face.

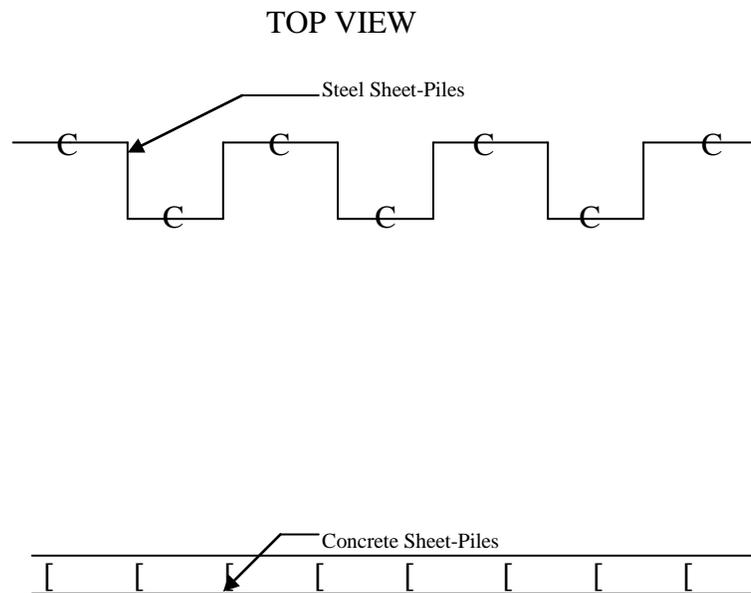


Reinforced Soil Slope (RSS)
Internally Stabilized Fill Wall

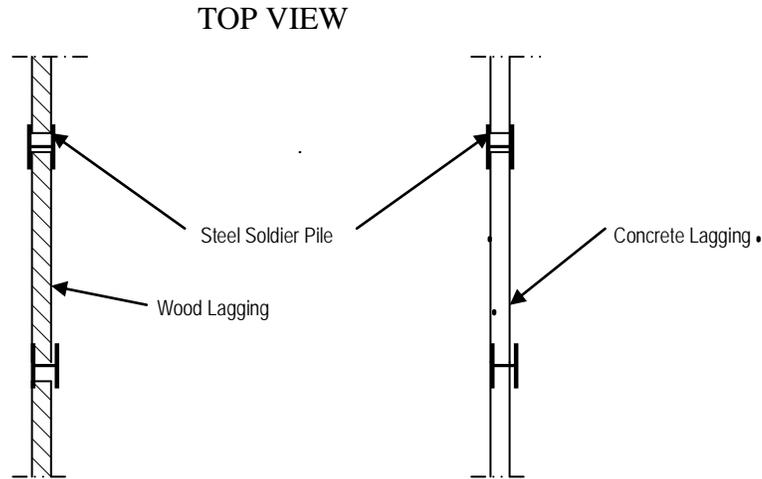
II. Cut Walls

A) Non-gravity Cantilevered Walls- Externally Stabilized Cut Wall

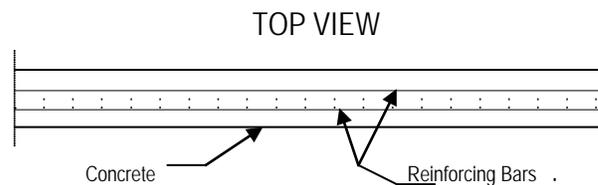
- 1) **Sheet-Pile Wall** – A sheet-pile wall consists of driven, vibrated, or pushed, interlocking steel or concrete sheet piles sections. The required depth of embedment (i.e., length of sheet-pile below final excavated grade) is evaluated based on the assumption that the passive resistance of the soil in front of the wall plus the flexural strength of the sheet-pile can resist the lateral forces from the soil behind the wall. Sheet pile walls can be constructed with anchors.



- 2) **Soldier Pile and Lagging Wall**- A soldier pile and lagging wall is a non-gravity cantilevered wall which derives lateral resistance and moment capacity through embedment of vertical wall elements (soldier piles). The soil behind the wall is retained by lagging. The vertical elements may be drilled or driven steel or concrete piles. These vertical elements are spanned by lagging which may be wood, reinforced concrete, precast or CIP concrete panels, or reinforced shotcrete.



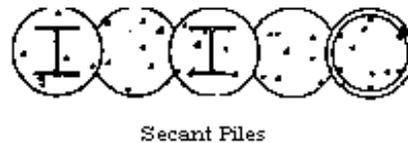
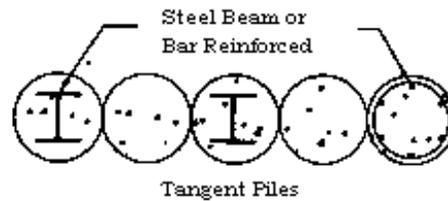
- 3) **Slurry (Diaphragm) Wall**- A slurry (diaphragm) wall is a continuous concrete wall consisting of either steel-reinforced CIP concrete or precast concrete panels that are constructed within an excavated trench. A temporary concrete guidewall is built to maintain the alignment. The trench is constructed from the surfaces and is stabilized with a mineral or polymer slurry as the excavation proceeds. As an individual section of wall (panel) is excavated, the slurry is cleared of sediments so that subsequently placed tremie concrete will fully displace the slurry. For a CIP panel, a reinforcing cage is inserted into the trench and a high slump concrete is then tremied into the trench. Following a specified set time, the next panel is constructed. After Construction, the ground in front of the wall is excavated to final grade.



Slurry (Diaphragm) Wall- Reinforcing Bars

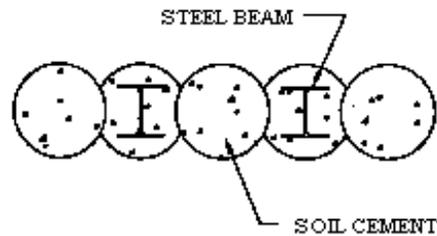
- 4) **Tangent Pile/Secant Pile Wall-** A tangent pile wall consists of a single row of tangentially touching drilled, reinforced-concrete piles. The reinforcement of each pile may consist of a steel beam, a single reinforcing bar, or a reinforcing bar cage. A secant pile wall consist of a single line of alternating drilled, reinforced and unreinforced concrete piles. Alternating unreinforced piles are constructed and allowed to set for a short period of specified time. Subsequently, a reinforced concrete pile is constructed between the previously drilled piles by cutting through a section of the previously constructed concrete piles. Tangent pile and secant pile walls can be constructed for permanent applications.

TOP VIEW

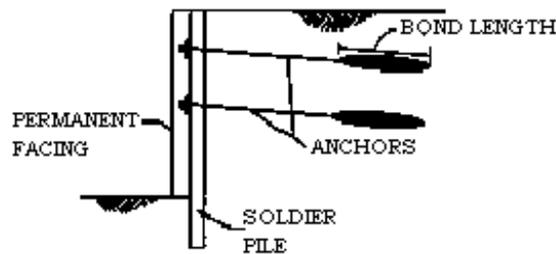


- 5) **Soil Mixed Wall (SMW)**- A soil mixed wall consists of overlapped soil-cement columns in which in-situ soils are mixed with a cement slurry or other hardening agent. A multiple axis auger and mixing paddles are used to construct overlapping soil-cement columns without soil removal or unmixed zones between columns. Steel structural members are typically used for reinforcement and are placed into alternating columns before substantial hardening of the soil-cement takes place. The unreinforced soil-cement columns are designed to resist and redistribute horizontal stress to adjacent reinforced members. Soil mix walls are typically constructed using anchors. Precast panels or CIP concrete may be constructed for permanent applications.

TOP VIEW



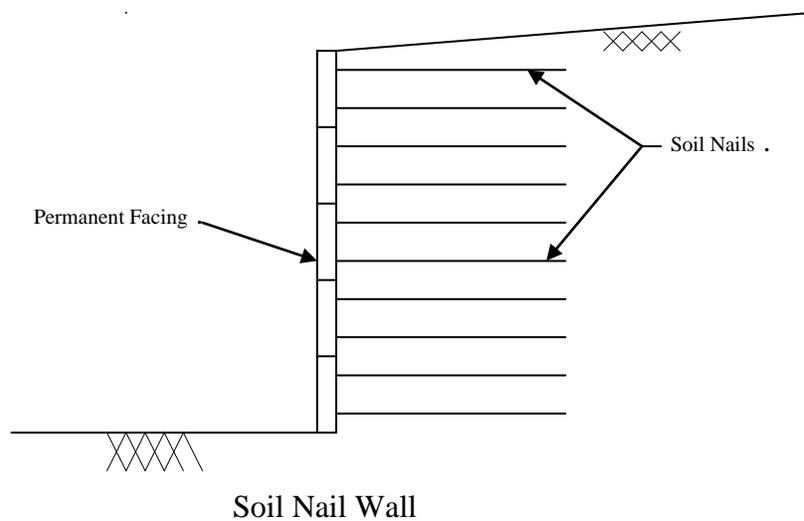
- 6) **Anchored Wall**- An anchored wall is any non-gravity cantilevered wall (i.e., sheet-pile wall, soldier pile and lagging wall, slurry (diaphragm) wall, tangent pile/secant pile wall, or soil mixed wall (SMW)) which relies on one or more levels of ground anchors (tiebacks) or deadman anchors for additional lateral support. The use of anchors enables these walls to be higher and deflect less than walls without anchors, (i.e., cantilever walls). An anchor is a structural system designed to transmit tensile loads to the retained soil behind a potential slip surface. Construction of the vertical wall elements and lagging (if required) for an anchored wall proceeds from the top-down as for all non-gravity cantilevered walls. When the elevation of the excavation in front of the wall reaches approximately 3 feet below the specified elevation of an anchor, the process of excavation is temporarily suspended and anchors are installed at the specified elevation. An anchor is installed using drilling and grouting procedures consistent with the anchor type and prevailing soil conditions. Each anchor is tested following its installation. Typical permanent facing panels include CIP or precast concrete with natural, textured, or architectural finishes.



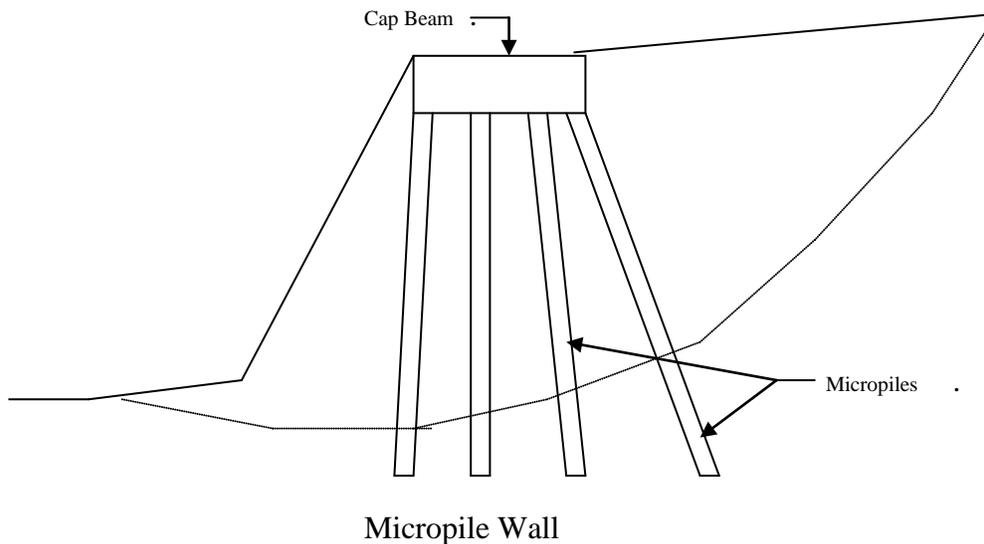
Anchored Wall

B) In-situ Reinforced Wall- Internally Stabilized Cut Wall

- 1) **Soil-Nailed Wall**- Soil nailing is an in-situ soil reinforcement technique wherein passive inclusions (soil nails) are placed into the natural ground at relatively close spacing (e.g., 3.0 to 6.0 feet) to increase the strength of the soil mass. Construction is staged from the top-down and, after each stage of excavation, the nails are installed, drainage systems are constructed, and shotcrete is applied to the excavation face. If the wall is permanent, shotcrete or CIP concrete facing panels may be installed after the wall is complete.



- 2) **Micropile Wall-** Micropile walls (i.e., root-pile walls and insert walls) consist of an array of drilled and grouted micropiles that penetrate below a potential surface of sliding. For these wall systems, the micropiles are connected at the ground surface to a reinforced concrete cap beam. The design of a root-pile wall uses small diameter piles spaced closely together in a complex three-dimensional network. The purpose of this micropile system is to “knit” the soil into a coherent mass that behaves as a gravity-retaining structure. The vertical and battered piles of an insert wall are larger in diameter and are spaced farther apart in comparison to a root-pile wall. This wall system provides sliding resistance through tensile and flexural resistance developed in the piles.



III. Geotechnical Investigation

The engineering properties and behavior of backfill, retained soil, and foundation material must be evaluated because these materials are the major sources of both loading and support for any earth retaining system. The evaluation of retained soil and foundation materials is typically made through a geotechnical subsurface investigation and borrow source evaluation and a laboratory or in-situ testing program. The evaluation of backfill material is typically made through a laboratory testing program.

IV. Wall System Selection

Refer to Chapter 1 - Section 2.0 of the TDOT Policy Regarding Earth Retaining Structures for a discussion of factors to consider in the selection of an earth retaining structure. Also refer to Tables 1 and 2 on pages 18 and 19 of this Chapter for further guidance.

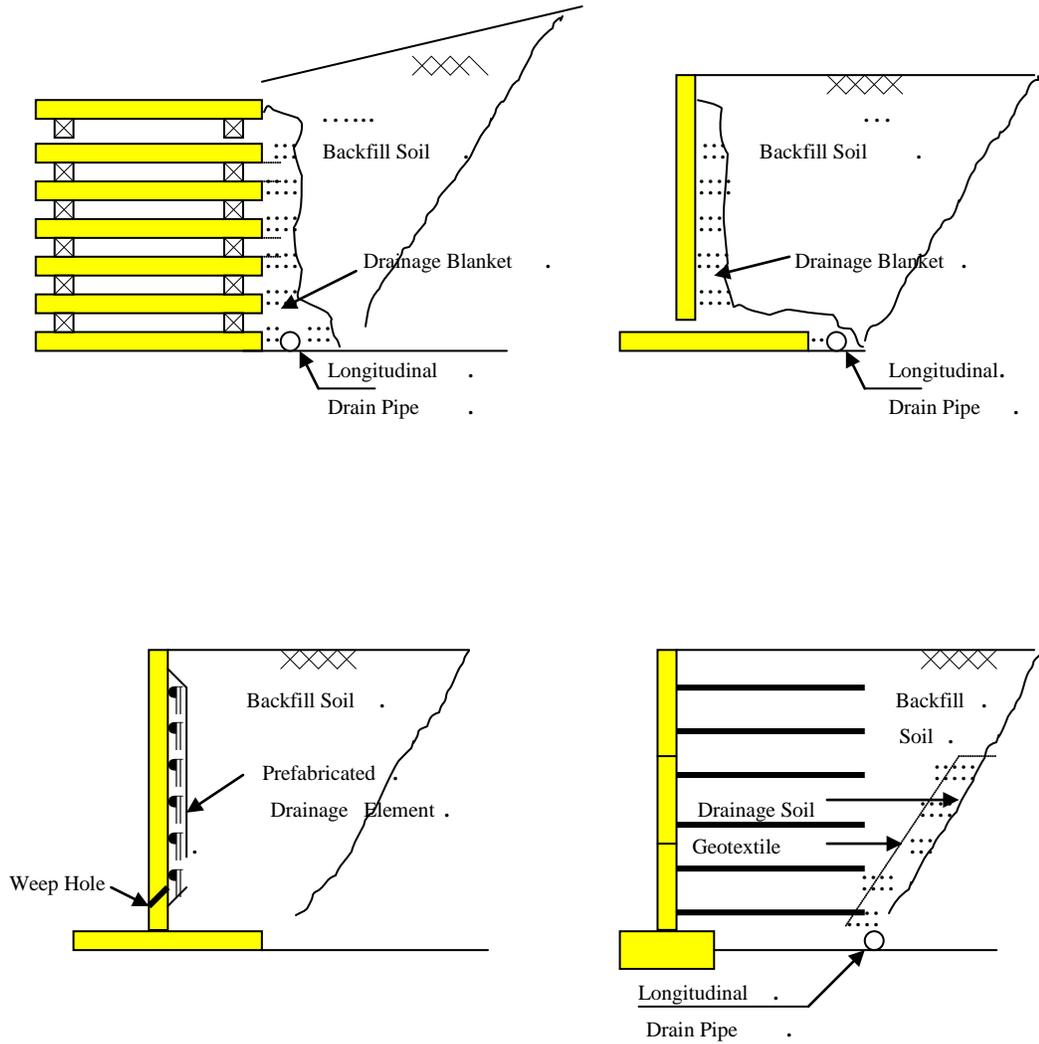
V. Wall Drainage Systems

Drainage System for Fill Walls:

Appropriate drainage measures to prevent surface water from infiltrating into the wall backfill should be included in the design of a wall system. During construction, the backfill surface should be graded away from the wall at the end of each day of construction to prevent water from ponding behind the wall and saturating the soil.

Drainage System for Cut Walls:

The need for drainage in cut wall system applications varies with project requirements. Drainage systems may be omitted in cases where ground-water draw down in the retained soil is prohibited or undesirable. In other cases, drainage is used as a means to control surface-water infiltration and ground-water seepage.



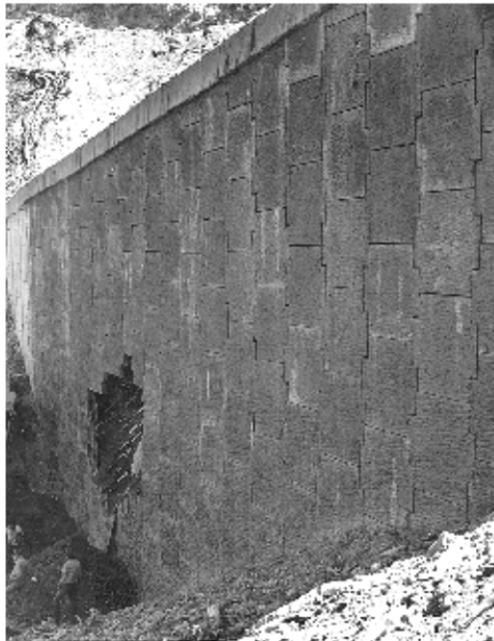
Drainage System For Fill Walls

VI. Construction

During construction there are many factors that affect the loading on a retaining wall. Following are a few one should be aware of:

- 1) Types of backfill
- 2) Drainage of backfill material
- 3) Backfill overloads (heavy equipment)
- 4) Placement of backfill
- 5) Type of material beneath footing

Careful planning, study, design, etc. can be rendered useless if the wall is not constructed according to plans & specifications. If existing field conditions do not agree with plans, the engineer and/or geologist should be contacted.



This photo was taken in the mid 1980's. Shown is the failure of a Reinforced Earth retaining wall. This failure was one of several which occurred during construction of the Foothills Parkway in Blount County, Tennessee. Approximately 33 factors were identified by the FHWA as contributing to this failure. Probably, the most significant factor was improper placement of backfill.

Table 1. System selection chart for fill walls.

Wall Type	Perm.	Temp.	Cost Effective Height Range	Cost in \$ per ft ² of wall face ⁽¹⁾	Required ROW ⁽²⁾	Differential Settlement Tolerance ⁽³⁾	Advantages	Disadvantages
Concrete Gravity wall			3-10 ft	25-35	0.5-0.7H ⁽⁴⁾	1/500	<ul style="list-style-type: none"> • durable • requires smaller quantity of select backfill as compared to MSE walls • concrete can meet aesthetic requirements 	<ul style="list-style-type: none"> • deep foundation support may be necessary • relatively long construction time
Concrete cantilever wall	✓		6-30 ft	25-60	0.4-0.7H ⁽⁴⁾	1/500	<ul style="list-style-type: none"> • durable • requires smaller quantity of select backfill as compared to MSE walls • concrete can meet aesthetic requirements 	<ul style="list-style-type: none"> • deep foundation support may be necessary • relatively long construction time
Concrete counterforted wall	✓		30-60 ft	25-60	0.4-0.7H ⁽⁴⁾	1/500	<ul style="list-style-type: none"> • durable • requires smaller quantity of select backfill as compared to MSE walls • concrete can meet aesthetic requirements 	<ul style="list-style-type: none"> • deep foundation support may be necessary • relatively long construction time
Concrete crib wall	✓		6-35 ft	25-35	0.5-0.7H	1/300	<ul style="list-style-type: none"> • does not require skilled labor or specialized equipment • rapid construction 	<ul style="list-style-type: none"> • difficult to make height adjustments in field
Metal bin wall	✓		6-35 ft	25-35	0.5-0.7H	1/300	<ul style="list-style-type: none"> • does not require skilled labor or specialized equipment • rapid construction 	<ul style="list-style-type: none"> • difficult to make height adjustments in field • subject to corrosion in aggressive environment
Gabion wall	✓		6-26 ft	25-50	0.5-0.7H	1/50	<ul style="list-style-type: none"> • does not require skilled labor or specialized equipment 	<ul style="list-style-type: none"> • need adequate source of stone • construction of wall requires significant labor
MSE wall (precast facing)	✓		10-65 ft	22-35	0.7-1.0H	1/100	<ul style="list-style-type: none"> • does not require skilled labor or specialized equipment • flexibility in choice of facing 	<ul style="list-style-type: none"> • requires use of select backfill • subject to corrosion in aggressive environment (metallic reinforcement)
MSE wall (modular block facing)	✓		6-23 ft	16-26	0.7-1.0H	1/200	<ul style="list-style-type: none"> • does not require skilled labor or specialized equipment • flexibility in choice of facing • blocks are easily handled 	<ul style="list-style-type: none"> • requires use of select backfill • subject to corrosion in aggressive environment (metallic reinforcement) • positive reinforcement connection to blocks is difficult to achieve
MSE wall (geotex/geogrid/welded wire face)	✓	✓	6-50 ft	15-35	0.7-1.0H	1/60	<ul style="list-style-type: none"> • does not require skilled labor or specialized equipment • flexibility in choice of facing 	<ul style="list-style-type: none"> • facing may not be aesthetically pleasing • geosynthetic reinforcement is subject to degradation in some environments
Reinforced Soil Slopes (RSS)	✓	✓	10-100 ft	7-24	0.5-1.0H	1/60	<ul style="list-style-type: none"> • does not require skilled labor or specialized equipment • flexibility in choice of facing • vegetation provides ultraviolet light protection to geosynthetic reinforcement 	<ul style="list-style-type: none"> • facing may not be aesthetically pleasing • geosynthetic reinforcement is subject to degradation in some environments • vegetated soil face requires significant maintenance

Notes (1) Total installed costs in 1995 U.S. dollars.

(2) ROW requirements expressed as the distance (as a fraction of wall height, H) behind the wall face where fill placement is generally required for flat backfill conditions, except where noted.

(3) Ratio of the difference in vertical settlement between two points along the wall to the horizontal distance between points.

(4) ROW requirements given is the typical wall base width as a fraction of wall height, H.

Table 2. System selection chart for cut walls.

Wall Type	Perm.	Temp.	Cost Effective Height Range	Cost in \$ per ft ² of wall face ⁽¹⁾	Required ROW ⁽⁵⁾	Lateral Movements	Water Tightness	Advantages	Disadvantages
Sheet-pile wall	✓	✓	up to 16 ft	15-40	none	large	fair	<ul style="list-style-type: none"> • rapid construction • readily available 	<ul style="list-style-type: none"> • difficult to construct in hard ground or through obstructions
Soldier pile/lagging wall	✓	✓	up to 16 ft	10-35	none	medium	poor	<ul style="list-style-type: none"> • rapid construction • soldier piles can be drilled or driven 	<ul style="list-style-type: none"> • difficult to maintain vertical tolerance in hard ground • potential for ground loss at excavated face
Slurry (diaphragm) wall	✓	✓	20-80 ft ⁽²⁾	60-86	none ⁽⁶⁾	small	good	<ul style="list-style-type: none"> • can be constructed in all soil types or weathered rock • watertight • wide range of wall stiffness 	<ul style="list-style-type: none"> • requires specially contractor • significant spoil for disposal • requires specialized equipment
Tangent pile wall	✓	✓	10-30 ft 20-80 ft ⁽²⁾	40-75	none ⁽⁶⁾	small	fair	<ul style="list-style-type: none"> • adaptable to irregular layout • can control wall stiffness 	<ul style="list-style-type: none"> • difficult to maintain vertical tolerances in hard ground • significant spoil for disposal • requires specialized equipment
Secant pile wall	✓	✓	10-30 ft 20-80 ft ⁽²⁾	40-75	none ⁽⁶⁾	small	fair	<ul style="list-style-type: none"> • adaptable to irregular layout • can control wall stiffness 	<ul style="list-style-type: none"> • significant spoil for disposal • requires specialized equipment
Soil mixed wall	✓	✓	20-80 ft ⁽²⁾	45-55	none ⁽⁶⁾	small	fair	<ul style="list-style-type: none"> • adaptable to irregular layout 	<ul style="list-style-type: none"> • requires specialized equipment • relatively small bending capacity
Anchored wall	✓	✓	16-65 ft ⁽³⁾	15-75	0.60H + anchor bond length	small-medium	N/A	<ul style="list-style-type: none"> • can resist large horizontal pressure • adaptable to varying site conditions 	<ul style="list-style-type: none"> • requires skilled labor and specialized equipment • anchors may require permanent easements
Soil-nailed wall	✓	✓	10-65 ft	15-56	0.6-1.0H	small-medium	N/A	<ul style="list-style-type: none"> • rapid construction • adaptable to irregular wall alignment 	<ul style="list-style-type: none"> • nails may require permanent easements • difficult to construct and design below water table
Micropile wall	✓		N/A	300-900 ⁽⁴⁾	varies	N/A	N/A	<ul style="list-style-type: none"> • does not require excavation 	<ul style="list-style-type: none"> • requires specialty contractor

Notes: (1) Total installed costs in 1995 U.S. dollars.

(2) Height range given is for wall with anchors.

(3) For soldier pile and lagging wall only

(4) Cost per linear foot of wall

(5) ROW requirements expressed as the distance (as a fraction of wall height, H) behind the wall face where wall anchorage components (i.e., ground anchors and soil nails) are installed

(6) ROW required if wall includes anchors.

Chapter III

Retaining Wall Design and Construction Requirements

A. Cast-in-Place (CIP) Concrete Gravity Retaining Walls

1.0 Description

This section covers the design, submittal of working drawings, materials, construction, measurement, and payment for cast-in-place concrete and stone masonry gravity retaining walls. The scope of work of wall construction includes as required: all grading necessary for wall construction, undercutting and backfilling of weak surficial zones, compaction of wall foundation, general and local dewatering as required for proper execution of the work, formwork, placement and curing of concrete, texture coating or architectural treatment, placement of drainage materials, and placement of backfill. All other items included in the construction of the retaining wall not specifically mentioned herein shall conform to the applicable sections of the *Tennessee Department of Transportation Standard Specifications for Road and Bridge Construction*, henceforth referred to as the Standard Specifications, and the current *AASHTO Standard Specifications for Highway Bridges* with interims. The architectural treatment and/or texture finish of the walls shall be in accordance with the contract plans.

2.0 Design Criteria

The design of cast-in-place concrete and stone masonry gravity retaining walls shall be in accordance with the current *AASHTO Standard Specifications for Highway Bridges* with interims. The soil properties and specific design values shall be shown on the contract plans. Note that the use of TDOT's standard retaining wall drawings require select backfill material with a minimum internal friction angle of 33° 41'. Backfill with other angles of internal friction will require a different wall design

3.0 Submittals

Requirements for submittals are outlined in Chapter I, Section 4, Requirements for Contractor/Supplier Prepared Design Plans.

4.0 Materials

The materials used in the construction of the wall shall conform to section 604 of the Standard Specifications. Concrete shall be Class "A", cast-in-place, with a minimum $f'_c = 3000$ psi. Stone masonry shall be in accordance with Section 612 of the Standard Specifications. The sources for all backfill material shall be approved in conformance with the specifications before the material is delivered to the job site. Any select backfill material must be approved or tested for compliance prior to construction.

All concrete, reinforcing steel, and backfill materials shall be tested at the specified frequencies in accordance with the TDOT "Procedures for the Sampling and Testing, and Acceptance of Materials and Products (SOP 1-1).

5.0 Construction

The construction of the wall shall be in accordance with the Standard Specifications.

6.0 Method of Measurement

The method of measurement shall be the square foot area of the wall face, measured from the top of the footing to the top of the wall, excluding any appurtenances.

7.0 Basis of Payment

The cast-in-place concrete or stone masonry gravity retaining wall, complete in place and accepted, shall be paid for at the contract square foot bid price. The bid price for walls shall include as required: grading and compaction of the wall foundation, undercutting and backfilling of weak surficial zones, excavation, sheeting, shoring, concrete or stone masonry, architectural treatment or texture finish, drainage system, waterstops and joint sealing material, and all miscellaneous material and labor for the complete installation of the wall. If the contractor's design requires the use of select granular backfill, the unit price bid for the wall shall be full compensation for any additional backfill costs due to the use of select backfill material. If required for retaining wall protection against vehicle impact, the cost of the barrier wall and end terminals shall be included in the square foot cost of the wall.

B. Cast-In-Place (CIP) Concrete Cantilever And Counterfort Retaining Walls

1.0 Description

This section covers the design, submittal of working drawings, materials, construction, measurement, and payment for cast-in-place concrete cantilever and counterfort retaining walls. The scope of work of wall construction includes as required: all grading necessary for wall construction, undercutting and backfilling of weak surficial zones, compaction of wall foundation, general and local dewatering as required for proper execution of the work, installation of piling, formwork, placement of reinforcing steel, placement and curing of concrete, texture coating or architectural treatment, placement of drainage materials, and placement of backfill. All other items included in the construction of the retaining wall not specifically mentioned herein shall conform to the applicable sections of the *Tennessee Department of Transportation Standard Specifications for Road and Bridge Construction*, henceforth referred to as the Standard Specifications, and the current *AASHTO Standard Specifications for Highway Bridges* with interims. The architectural treatment and/or texture finish of the walls shall be in accordance with the contract plans.

2.0 Design Criteria

The design of cast-in-place concrete and cantilever and counterfort retaining walls shall be in accordance with the current *AASHTO Standard Specifications for Highway Bridges* with interims. The soil properties and specific design values shall be shown on the contract plans.

3.0 Submittals

Requirements for submittals are outlined in Chapter I, Section 4, Requirements for Contractor/Supplier Prepared Design Plans.

4.0 Materials

The materials used in the construction of the wall shall conform to the Standard Specifications. Concrete shall be Class "A" in accordance with section 604, cast-in-place, with a minimum $f'_c = 3000$ psi. Reinforcing steel shall conform to ASTM A 615, Grade 60. The sources for all backfill material shall be approved in conformance with the Standard Specifications before the material is delivered to the job site. Any select backfill material must be approved or tested for compliance prior to construction.

All concrete, reinforcing steel, and backfill materials shall be tested at the specified frequencies in accordance with the TDOT "Procedures for the Sampling and Testing, and Acceptance of Materials and Products (SOP 1-1)".

5.0 Construction

The construction of the wall shall be in accordance with the Standard Specifications. If the use of piles is anticipated, the foundation information shown on the contract plans shall include the skin friction (Fs) and end bearing (Qb) values, or the location of the rock line. Based on this information, estimated pile lengths shall be shown on the contract plans for fifty (50) and one hundred (100) tons ultimate bearing capacity for Size 1 concrete friction piles. The contractor shall estimate point bearing steel pile refusal lengths based on the given rock line information.

Concrete friction piles shall be installed to provide a minimum factor of safety of 2.0 if a load test is used and a minimum factor of safety of 3.0 if a load test is not used. Pile types, load test procedures, and driving equipment shall be in accordance with the Standard Specifications and shall be approved by the Engineer. The number and location of test piles and load tests shall be approved by the Engineer. Test pile lengths shall be ten (10) feet longer than the estimated pile lengths. Test piles shall be driven in accordance with the Standard Specifications, and shall be required at least every fifty (50) feet along the wall, unless otherwise approved by the Engineer. No pile shall be any farther than five hundred (500) feet from a load test, if a load test is used, unless otherwise approved by the Engineer. The length of production piles to be driven and the required bearing based on the driving equation shall be determined by the Engineer based on the required design bearing, the results of the test piles and load tests (if used), and applicable safety factors. Driven pile lengths and final bearings shall be approved by the Engineer.

Point Bearing Steel Piles shall be driven to refusal. Pile tips shall be used when indicated on the contract plans.

All reinforcing steel projecting from footing into the wall in the back face (fill side) shall be epoxy coated.

6.0 Method of Measurement

The method of measurement shall be the square foot area of the wall face, measured from the top of the footing to the top of the wall excluding any appurtenances. .

7.0 Basis of Payment

The cast-in-place concrete cantilever or counterfort retaining wall, complete in place and accepted, shall be paid for at the contract square foot bid price except as noted below for increases in wall height. The bid price for walls shall include as required: grading and compaction of the wall foundation, footing excavation, installation of foundation improvements as required in the Wall Concept Drawings such as undercutting to certain elevations or materials and replacing with a prescribed select material, installation of geo-structural elements such as Geopiers, stone columns or other foundation improvement methods, pre-splitting, sheeting, shoring, concrete, reinforcing steel, architectural

treatment and/or texture finish, drainage system, waterstops and joint sealing material, and all miscellaneous material and labor for the complete installation of the wall. If the contractor's design requires the use of select granular backfill, the unit price bid for the wall shall be full compensation for any additional backfill costs due to the use of select backfill material. The square foot price bid for the wall shall also include as applicable the cost of the piles in place, load tests, test piles, cutoffs, splices and pile tips for steel piles, and seismic attachments.

If the actual driven quantity of concrete piles varies more than 10% from the estimated quantity based on the estimated lengths, an increase or decrease based on the contract bid price, or in the absence of a bid item, a price of twenty eight (28) dollars, per linear foot of additional or reduced pile length will be added or deducted accordingly from the price paid for the retaining wall. If the Engineer orders additional test piles, they will be paid for at the contract bid price, or in the absence of a bid item, a price of forty (40) dollars per linear foot. If the contractor changes friction pile types or sizes, additional load test(s) may be required at the Engineer's discretion and at the contractor's expense.

If the contractor uses a different type of pile than those that have estimated lengths shown on the contract plans, the price of the wall shall include all costs associated with piles and pile installation with no additional payment for any variation in pile lengths. All pile types and pile driving procedures, lengths, and bearings shall be in accordance with the Standard Specifications and shall be approved by the Engineer

The contractor shall show the estimated quantity of point bearing steel piles on the design drawings submitted for approval. If the actual quantity of steel piles driven differs more than 10% from this approved quantity because of variation in the rock line, the cost of the retaining wall will be increased or decreased accordingly based on the contract bid price, or in the absence of a bid item an unit price of thirty five (35) dollars per linear foot, for the adjusted piling quantity.

If the Engineer orders changes in the work, which alters the exposed surface area of the wall without increasing the height of the wall, payment will be increased or decreased accordingly based on the square foot bid price. If the Engineer orders changes in the work which increases the height of the wall, the unit price bid for the wall sections that were increased up to a maximum of 10 feet will be adjusted according the following tables. Adjustments exceeding 10 feet will be made by supplemental agreement.

If required for retaining wall protection against vehicle impact, the cost of the barrier wall and end terminals shall be included in the square foot cost of the wall.

C. Concrete Crib Walls

1.0 Description

This section covers the materials, fabrication, construction, measurement, and payment for concrete crib type earth retaining structures. The scope of work includes but is not limited to any necessary foundation-soil improvements, grading and compaction of the wall foundation, installation of any drainage systems, general and local dewatering, construction of leveling pads, bin erection, compaction of cribfill material, and compaction of backfill material. All items not specifically addressed in this section shall conform to the latest applicable sections of the *Tennessee Department of Transportation Standard Specifications for Road and Bridge Construction* with interims henceforth referred to as the Standard Specifications.

2.0 Design Criteria

The current *AASHTO Standard Specifications for Highway Bridges* with interims shall be used as a basis for design.

3.0 Submittals

Requirements for submittals are outlined in Chapter I, Section 4, Requirements for Contractor/Supplier Prepared Plans.

4.0 Materials

The following items are the construction materials requirements necessary for crib wall design fabrication. All materials shall be approved prior to use.

4.1 Pre-Cast Concrete Crib Units

The pre-cast crib units are to be made of Class D Portland cement concrete conforming with Section 604 of the Standard Specifications.

- 4.1.1 Coarse aggregate shall meet the requirements of section 903.02 and be size No. 57 from the table found on Standard Specifications 903.22.
- 4.1.2 Fine aggregates shall conform to the requirements established in Section 903.01.
- 4.1.3 Type I or Type III Portland cement may be used at a minimum rate of 620 lb. per cubic yard.
- 4.1.4 Any chemical additives (water reducers, plasticizers, air entraining admixtures) the Contractor submits must conform to the requirements of

AASHTO M 194 and meet all of other requirements set forth in Section 918.09 of the Standard Specifications.

- 4.1.5 Water to be used must conform to Section 918.01.
 - 4.1.6 Calcium chloride or any admixture containing calcium chloride will not be permitted.
 - 4.1.7 Cast-in-place concrete for caps, copings, and end sections may be of Class A concrete adhering to all of the requirements of Section 604.
 - 4.1.8 All reinforcing steel shall conform to the requirements of ASTM A 615, Grade 60.
 - 4.1.9 Lifting hooks and threaded inserts shall be of the size indicated on the working drawings.
 - 4.1.10 When required, imbedded items must be galvanized in accordance with ASTM A 153.
- 4.2 Crib Backfill
- All backfill material shall be tested prior to use and at the established frequencies in the TDOT “Procedures for the Sampling and Testing, and Acceptance of Materials and Products (SOP 1-1)”.
- 4.2.1 The crib backfill material shall consist of an AASHTO classified A-1-a, A-1-b, or A-3 soil with the additional requirement no more than ten percent by weight pass the #200 sieve.
 - 4.2.2 The unit weight of the crib fill should be a minimum 115 lb. per cubic foot.
 - 4.2.3 Filter protection (geotextile) may be required.
- 4.3 Backfill Behind the Crib Type Structure
- All backfill material shall be tested prior to use and at the established frequencies in the TDOT “Procedures for the Sampling and Testing, and Acceptance of Materials and Products (SOP 1-1)”.
- 4.3.1 If a filter blanket is placed behind the wall, native soil may be used as backfill behind the structure.
 - 4.3.2 Select fill, as defined in 4.2.1 of this document, can be used as backfill behind the structure. The backfill unit weight must be a minimum of 115 pcf. An internal angle of friction can be assumed equal to 35 degrees.

5.0 Fabrication of Precast Concrete Crib Units

- 5.1 All pre-cast concrete shall be produced in an approved plant in accordance with the TDOT Procedure for the “Manufacture and Acceptance of Pre-cast Concrete Drainage Structures, Noise Wall panels, and Retaining wall panels”.

Out-of-state producers shall provide documentation of material quality before the manufacture of any pre-cast products (i.e. aggregate quality reports, cement/steel mill test reports, etc.)

The fabricator shall provide two precast modular units to the Engineer for approval.

- 5.1.1 These approved precast modular units will serve as standard models. The finished exposed faces of the production precast modular units should be similar to the exposed faces of the model precast modular units.

- 5.1.2 One of the model precast modular units should be kept at the production plant for relative comparison to future modular units. The other model should be kept on the construction site for comparison to the other delivered units.

- 5.2 To assure uniform unit production steel forms must be used.
- 5.3 The placement of reinforcing steel within the precast units should conform to the design placement shown in the shop drawings.
- 5.4 Final acceptability of the precast units shall be determined on the basis of compression tests, production defects and tolerances, and visual inspection. The manufacturer shall furnish all sampling and testing facilities.
- 5.5 Section 604 of the Standard Specifications states the units shall be steam or moist cured until developing the specified compressive strength set forth in the shop drawings. Any unit not developing the specified compressive strength shall be rejected.
- 5.6 The precast units should not be delivered before samples have attained the required compressive strength of 4,000 psi (f'_c).
- 5.7 Prior to shipment, the finished units are subject to visual inspection by the Engineer. Individual crib units may be rejected for any of the reasons listed below.
- 5.7.1 Variations in the exposed face texture relative to the approved model face texture.

- 5.7.2 The length or height of the unit not satisfying the unit allowable tolerance limit of 3/16”.
- 5.7.3 Honeycombed or open texture units which are not properly repaired.
- 5.7.4 Individual defects which could affect the structural integrity of the unit.

TDOT will verify products before shipment in accordance with the TDOT Procedure for the “Manufacture and Acceptance of Pre-cast Concrete Drainage Structures, Noise Wall panels, and Retaining wall panels”. If products are manufactured out of state, TDOT may verify at the project site PRIOR to the placement of the units. The Contractor, or producer, shall notify the Regional Materials and Tests Division that products need to be verified.

- 5.8 Upon delivery, the exposed surface of the precast units shall be examined. If the exposed faces of any of the units are below the standards of the approved model on site, the units shall be replaced or properly repaired until conforming to the appearance, strength, and durability of the approved model.
- 5.9 The date of manufacture shall be clearly and permanently marked on one of the inside surfaces of each unit. Each shipment must be accompanied with a certification letter as stated in the TDOT Procedure for the “Manufacture and Acceptance of Pre-cast Concrete Drainage Structures, Noise Wall panels, and Retaining wall panels

6.0 Construction

- 6.1 The Contractor should perform any soil improvement, such as undercutting and backfilling before foundation preparation.
- 6.2 Compact the top 12” of soil on which the structure will rest to at least 95% of the maximum laboratory dry density as specified in AASHTO T-99.
- 6.3 No Crib-type wall should be built upon frozen ground.
- 6.4 Following excavation for the crib wall system, the Contractor shall notify the Engineer for approval of the footing depth and character of the foundation material. No crib wall system work shall proceed until approval has been granted.
- 6.5 The correct batter of the wall shall not exceed ½” per 10 ft. of wall height.
- 6.6 The crib backfill should be placed and compacted to at least 95% of the maximum laboratory dry density (AASHTO T-99) in layers no thicker than 12”.
- 6.7 Backfilling behind the crib system shall follow erection as closely as possible. The wall height should never be greater than three feet above the backfill.

- 6.8 Any underdrain shall be placed in accordance with the details of the working plans.
- 6.9 The Contractor shall furnish, install, operate, and maintain satisfactory dewatering systems as required to maintain the site in a dry and workable condition. These systems shall be continued as long as necessary. No separate measurement or payment will be made for dewatering.

7.0 Methods of Measurement

The crib-type walls will be measured in terms of square feet of surface area of the wall face.

8.0 Basis of Payment

- 8.1 The bid is to be submitted in terms of dollars per square foot.
- 8.2 Bidding Contractors will be given the rough dimensions (height, length, and grade) of the proposed crib-type wall.
- 8.3 Areas of wall, which are beneath grade, will not be eligible for compensation.
- 8.4 The contract bid price shall be full compensation for every activity associated with construction of the wall. These activities include but are not limited to the following items.
 - 8.4.1 Pre-construction Engineering
 - 8.4.2 Working plans and drawings
 - 8.4.3 Fabrication
 - 8.4.4 Delivering and erecting bin units
 - 8.4.5 Rock pre-splitting
 - 8.4.6 Excavation
 - 8.4.7 Shaping of cuts
 - 8.4.8 Select backfill
 - 8.4.9 Drainage systems
 - 8.4.10 If required for retaining wall protection against vehicle impact, the cost of the barrier wall and end terminals shall be included in the square foot cost of the wall.

D. Bin Wall

1.0 Description

This section covers the design, working drawings, materials, construction, measurement and payment for concrete bin walls. The scope of work of wall construction includes as required: all grading necessary for wall construction, undercutting and backfilling of weak surficial zones, compaction of wall foundation, general and local dewatering as required for proper execution of the work, formwork, placement and construction of leveling footings, texture coating or architectural treatment as shown on contract plans, placement of drainage systems as specified on the plans, erection of modular units, and the placement and compaction of the soils within the units and behind the units, as well as the construction of any required reinforced concrete appurtenances such as caps, copings or end sections as specified. For the purpose of this section, the wall foundation shall include all areas underlying the leveling footing and the modular units. All other items included in the construction of the retaining wall not specifically mentioned herein this manual shall conform to the applicable sections of the *Tennessee Department of Transportation Standard Specifications For Road And Bridge Construction- March 1, 1995* and the current *AASHTO Standard Specifications for Highway Bridges with Interim Specifications*. Future reference to the *Tennessee Department of Transportation Standard Specification For Road And Bridge Construction-March 1, 1995* will be made as Standard Specifications.

2.0 Design Criteria

The current *AASHTO Standard Specifications for Highway Bridges with Interim Specifications* shall be used as the basis for design.

3.0 Submittals

Working drawings and design calculations shall be submitted to the Engineer for review and approval at least 60 days before wall construction is to begin. See Chapter I, Section 4.0 for contractor/supplier submittal responsibilities. The Contractor shall not start work on the bin wall until the working drawings have been approved by the Engineer. Approval of the Contractor's working drawings shall not relieve the Contractor of any responsibility under the contract for the successful completion of the work.

4.0 Materials

4.1 Concrete: The concrete for the precast units shall conform to the requirements of Section 604 of the Standard Specifications as follows:

Concrete for the precast modular units shall be air-entrained composed of portland cement, fine and coarse aggregates, admixtures and water. The air-entraining feature may be obtained by the use of either air-entraining portland cement or an approved air-entraining admixture. The entrained air content shall be not less than 4 percent or more than 7 percent at the time concrete is deposited in the forms. The concrete utilized shall be a mix that will attain a minimum 28 days strength (f'c) of 5000 psi. The mix design will be furnished to the Engineer.

- 4.1.1 Coarse aggregate shall consist of crushed stone having a maximum size of ¾ inches. An abrasion loss of 40 percent or less in the Los Angeles test and a sodium sulfate soundness loss (AASHTO T104) less than 9.0% shall be required.
- 4.1.2 Type I or Type III portland cement may be used. A minimum of 658 pounds per cubic yard of concrete shall be used.
- 4.1.3 Water-Reducing Admixtures: The Contractor may submit, for approval of the Engineer, water-reducing admixtures for the purpose of increasing workability and reducing the water requirement for the concrete.
- 4.1.4 Calcium Chloride: The addition to the mix of calcium chloride or admixtures containing calcium chloride will not be permitted.
- 4.2 Concrete for toe footings and cast-in-place concrete for parapets shall attain a minimum 28 day strength (f'c) of 3000 psi conforming to the applicable portions of Section 604 of the Standard Specifications.
- 4.3 Reinforcing Steel: All reinforcing steel shall conform to the requirements of AASHTO M 31 or ASTM A 615, Grade 40 or 60.
- 4.4 Lifting Hooks and Threaded Inserts: Devices and attachments shall be of the size indicated on the plans or of a design satisfactory for the purpose intended.
- 4.5 Imbedded items, when required, shall conform to details on the plans and be galvanized in accordance with AASHTO M 232 or ASTM A 153.
- 4.6 Filler for horizontal joints between modular units shall be resin-bonded cork filler or closed cell foam, cross linked polyethylene polymer, conforming to test requirements of AASHTO M 153 or ASTM D 1752 (Type II) or equal. Filter fabric placed behind front vertical joints shall be at least 6" wide and conform to section 918.27 of the TDOT Standard Specifications).

- 4.7 Backfill: All select granular material shall be free from shale and organic or otherwise deleterious material and conform to the following gradation limits:

<u>Sieve Size</u>	<u>Percent Passing</u>
6 inch	100
3 inch	75-100
No. 200	0-15

The Contractor, at his option, may produce the select granular material by processing the excavation from the project or from approved material from other sources. No direct payment will be made for producing the select granular material.

All backfill material shall be tested prior to use and at the established frequencies in the TDOT “Procedures for the Sampling and Testing, and Acceptance of Materials and Products (SOP 1-1)”.

- 4.8 Bearing pads shall be rubber of size, and manufacture shown on shop drawings, with the following properties perpendicular to the pad thickness:

Compression- minimum ultimate strength 8000 psi
Initial Cracking Strain- 40% of thickness
Hardness (Shore A) – 75 +/- 5
Tensile Strength- ASTM D 412, die “C”, 1000 psi +/- 100 psi
Tear Strength- ASTM D 624, die “B” – 360 psi minimum

- 4.9 Acceptance of materials furnished for work will be in accordance with the TDOT “Procedures for the Sampling and Testing, and Acceptance of Materials and Products (SOP 1-1) and certified test reports as specified in Section 106 – Control of Materials supplemented by routine tests run by the Department as defined in the various applicable sections of the Standard Specifications.

5.0 Construction

5.1 Bin Fabrication

- 5.1.1 All pre-cast concrete shall be produced in an approved plant in accordance with the TDOT Procedure for the “Manufacture and Acceptance of Pre-cast Concrete Drainage Structures, Noise Wall panels, and Retaining wall panels”.

Out-of-state producers shall provide documentation of material quality before the manufacture of any pre-cast products (i.e. aggregate quality reports, cement/steel mill test reports, etc.)

Before proceeding with production, a model precast modular unit shall be provided by the fabricator for the Engineer's approval to establish a guide and standard for the type of finish to be furnished on the exposed face. This model shall be kept at the fabricator's plant to be used for comparison purposes during production. Formed surfaces other than the exposed face shall not require a special finish

- 5.1.2 Forms: Forms for the units shall be constructed of steel with dimensional tolerances that will assure the production of uniform units. Finish for the front face of the wall shall be in accordance with the finish specified on the contract plans.
- 5.1.3 Mixing and Placing Concrete: The concrete mix as designed shall be proportioned and mixed in a batch mixer to produce a homogeneous concrete. The transporting, placement, and compaction of concrete shall be by methods that will prevent segregation of the concrete materials and the displacement of the reinforcement steel from its proper position in the form. Concrete shall be carefully placed in the forms and vibrated sufficiently to produce a surface free from imperfections such as honeycomb, segregation or cracking. Clear form oil of the same manufacture shall be used throughout the casting operation.
- 5.1.4 Reinforcing Steel: All reinforcing steel for the precast modules and other components shall be fabricated and placed in accordance with plans and Standard Specifications.
- 5.1.5 Testing and Inspection: Acceptability of the precast units at the casting yard shall be determined on the basis of compression tests and visual inspection during casting. The manufacturer shall furnish such facilities and assistance as is required to carry on the sampling and testing in an expeditious and satisfactory manner. The manufacturer shall document and provide all test data and certify in accordance with the TDOT Procedure for the "Manufacture and Acceptance of Pre-cast Concrete Drainage Structures, Noise Wall panels, and Retaining wall panels".
- 5.1.6 Curing: The units shall be steam or moist cured as specified in Section 604 of the Standard Specifications for a sufficient length of time so that the concrete will develop the specified compressive strength. Any panel which does not reach specified strength within 28 days shall be rejected.
- 5.1.7 Compressive Strength: Compressive tests to determine the minimum strength requirements shall be made on cylinders. A minimum of six

cylinders for determining when the units may be put into service will be made from each day's production and cured in accordance with AASHTO T 23 or ASTM C 31. The 28 day compressive strength shall be at least 5000 psi. Compressive strength tests shall be in accordance with AASHTO T 22 or ASTM C 39.

- 5.1.8 Rejection: The quality of materials, the process of manufacture, and the finished units shall be subject to inspection by the Engineer prior to shipment. Precast units may be subject to rejection on account of failure to conform to the requirements set forth herein. Individual units may be rejected because of any of the following:
- 5.1.8.1 Variations in the exposed face that substantially deviate from the approved model as to texture in accordance with precast concrete industry standards.
 - 5.1.8.2 Dimensions not conforming to the following tolerances:
 - Face of panel, length or height: plus/minus 3/16"
 - Deviation from square when measured on diagonal: 5/16" for modules up to 10' wide, 3/4" for larger units.
 - 5.1.8.3 Honeycombed or open texture not properly repaired.
 - 5.1.8.4 Defects which would affect the structural integrity of the unit.
- 5.1.9 Shipment: The precast units shall not be shipped until they have achieved the required concrete strength ($f'c$) of 5000 psi. TDOT will verify products before shipment in accordance with the TDOT Procedure for the "Manufacture and Acceptance of Pre-cast Concrete Drainage Structures, Noise Wall panels, and Retaining wall panels". If products are manufactured out of state, TDOT may verify at the project site PRIOR to the placement of the units. The Contractor, or producer, shall notify the Regional Materials and Tests Division that products need to be verified
- 5.1.10 Repairs at Plant: Before shipment, surfaces of all precast units shall be examined. If the exposed face of a unit is below the standard of the approved model then it shall be properly repaired to conform to the balance of the work with respect to appearance, strength and durability.
- 5.1.11 Handling and Storage: Handling devices, as required, shall be provided in each precast modular unit for the purpose of handling and placing. Care shall be taken during storage, transporting, hoisting and handling of all units to prevent cracking or damage. Units damaged by improper storing, transporting or handling shall be replaced or repaired to the satisfaction of the Engineer.

5.1.12 Marking: The date of manufacture and production lot number shall be clearly and permanently marked on the rear face of each unit.

5.2 Erection:

5.2.1 Foundation Preparation: The foundation for the bin wall shall be graded to the elevations and dimensions shown on the contract plans. Prior to wall construction, the top 12 inches of the foundation shall be compacted to at least 95% of the maximum laboratory dry density as determined by AASHTO T 99. Any foundation soils found to be unsuitable or incapable of sustaining the required compaction shall be removed and replaced. After the excavation for each location of the bin wall has been performed, the Contractor shall notify the Engineer. No concrete leveling footing shall be placed until the depth of excavation and the character of the foundation material has been approved by the Geotechnical Engineering Section of the Division of Materials and Tests and permission has been given to proceed by the Engineer.

5.2.2 At each unit foundation level, either a precast or cast-in-place footing and/or leveling pad shall be provided as shown on the shop drawings. The footings shall be given a wood float finish and shall reach the required compressive strength of 3000 psi, before placement of wall modules. The completed footing surface shall be constructed in accordance with grades and cross slopes shown on the shop drawings. When tested with a 10' straight edge, the surface shall not vary more than 1/8" in 10'. Any additional depth of footing required to level the top surface and bear on approved foundations shall be at the Contractor's expense.

5.2.3 The modular units shall be installed in accordance with the manufacturer's recommendations. Special care shall be taken in setting the bottom course of units to true line and grade. Joint filler and neoprene pads, when required, shall be installed in the horizontal joints. Joints at corners or angle points shall be closed as shown on the plans or in accordance with recommendation of the manufacturer.

5.2.4 All units above the first course shall interlock with the lower courses. Vertical joints shall be staggered with each successive course, or as shown on shop drawings. The vertical joint opening on the front face of the wall shall not exceed 3/4".

5.2.5 The interior of each successive course of precast modular units shall be filled with select granular backfill. The maximum lift thickness

- shall be 2 feet, and shall then be thoroughly consolidated with a vibratory tamping device.
- 5.2.6 Backfill behind the wall shall be compacted to at least 95 percent of the maximum laboratory dry density as defined in AASHTO T 99 to within one foot of the top of the wall. The top 12 inches shall be compacted to at least 100 percent of the maximum laboratory dry density.
- 5.2.7 When erecting a battered wall, placement of backfill behind the wall shall closely follow erection of successive courses of units. At no time shall the difference in elevation between the backfill and the top of the last erected course exceed seven feet.
- 5.2.8 The overall vertical tolerance of the wall shall not exceed 1/2 inch per 10 feet of wall as shown per plans.
- 5.2.9 Underdrain, if required, shall be placed in accordance with the details shown on the plans or shop drawings.
- 5.2.10 Storm Drains: Where required, precast concrete wall units shall be provided with the appropriate storm drain openings cast into units at the appropriate elevation and locations indicated on drainage profiles. Catch basins shall be located so pipes will enter perpendicular (plan view) to the precast wall units or below the leveling footing as shown on the plans. Construction of catch basins and placement of storm drains must be coordinated with the bin wall construction.
- 5.2.11 Cooperation between contractors: Contractors must coordinate all phases of the work to prevent delays and expedite construction.
- 5.2.12 Dewatering: The Contractor shall furnish, install, operate, and maintain satisfactory dewatering systems as required to maintain the site in a dry and workable condition so as to permit grading and compaction of the wall foundation and proper erection and backfill of the wall. These systems shall include all equipment and materials, and shall be continued as long as necessary. No separate measurement or payment will be made for dewatering.
- 5.2.13 Technical Consultations: The fabricator will be required as a part of the contract to provide on site technical expertise to the Contractor and/or the State upon request. Response to requests shall be required within five (5) days of the request. The cost of furnishing such technical consultations shall be at no cost to the State.

5.3 On Site Inspection

The quality of materials, the process of manufacture, and the finished member shall be subject to inspection and approval by the Engineer. Any bin wall units damaged prior to acceptance shall be repaired or reconstructed as directed by the Engineer. All costs of repairs or reconstruction shall be at the Contractor's expense.

5.4 Final Cleanup

Final cleanup shall be performed in accordance with the requirements of Section 104, Sub-Section 11, of the Standard Specifications.

5.5 Equipment

All equipment necessary for the satisfactory performance of the construction of bin walls shall be approved by the Engineer before construction will be permitted to begin.

6.0 Method of Measurement

Bin Walls are to be measured by the square foot of surface area of the wall face..

7.0 Basis of Payment

Payment for bin walls will be made by the square foot at the contract bid price which shall be full compensation for preconstruction engineering, preparation of the plans and working drawings, fabricating, delivering and erecting units, furnishing and placing joint fillers as specified, and for furnishing all incidental materials, pre-splitting, excavation, shaping of cuts, select backfill, drainage, and all other items of work necessary for the approved installation of walls.

Additional area of wall required due to unforeseen conditions or other reasons and approved by the Engineer will be paid for on the basis of the unit price bid. If required for retaining wall protection against vehicle impact, the cost of the barrier wall and end terminals shall be included in the square foot cost of the wall.

E. Gabion Wall

1.0 Description

This section covers the furnishing, assembling, filling with stone and tying open wire mesh rectangular compartmented gabions placed on filter cloth or filter stone as specified herein, and in reasonably close conformity with the lines, grades, dimensions, and cross-sections shown on the plans or as directed by the Engineer, and the design, working drawings, materials, construction, measurement and payment for gabions.

Included in the scope of this section are: grading and compaction of the wall foundation, general and local dewatering as required for proper execution of the work, installation of wall drainage systems as specified on the plans, erection of units, the placement of stone within the units and compaction of the soils behind the units as well as the construction of any required reinforced concrete appurtenances such as caps, copings, or end sections as specified on the plans. For the purposes of this section, the gabions foundation shall include all areas underlying the gabion wall. All other items included in the construction of the retaining wall not specifically mentioned herein this manual shall conform to the applicable sections of the *Tennessee Department of Transportation Standard Specifications for Road and Bridge Construction, March 1, 1995* and the current *AASHTO Standard Specifications for Highway Bridges with Interim Specifications*. Future reference to the *Tennessee Department Of Transportation Standard Specification For Road And Bridge Construction- March 1, 1995* will be made as Standard Specifications.

2.0 Design Criteria

The current AASHTO Standard Specifications for Highway Bridges with Interim Specifications shall be used as the basis for design.

3.0 Submittals

Working drawings and design calculations shall be submitted to the Engineer for review and approval at least 60 days before wall construction is to begin. See Chapter I, Section 4.0 for contractor/supplier submittal responsibilities. The Contractor shall not start work on the bin wall until the working drawings have been approved by the Engineer. Approval of the Contractor's working drawings shall not relieve the Contractor of any responsibility under the contract for the successful completion of the work.

4.0 Materials

4.1 Galvanized Steel Wire Mesh

Gabion basket units shall be of non-raveling construction and fabricated from a double twisted hexagonal mesh of hot-dipped galvanized steel wire having a minimum

diameter of 0.118 inches after galvanization. The steel wire used shall be galvanized prior to fabrication into mesh. All gabion diaphragm and frame wire shall equal or exceed ASTM A 853, ASTM A 818, ASTM A 641, ASTM A 809, possess an average tensile strength of 60,000 PSI, and a Finish 5 Class 3 zinc coating of not less than 0.80 oz/sq. ft. of uncoated wire surface. The weight of zinc coating shall be as determined by AASHTO T 65 or ASTM A 90. The uniformity of coating shall equal or exceed four (4) one minute dips by the Preece Test, ASTM A 239. Mesh openings shall be hexagonal in shape, and uniform in size measuring not more than 3-1/4 inches by 4-1/2 inches.

Selvedge or perimeter basket frame wire shall be of heavier gauge than the wire mesh with a minimum diameter after galvanization of 0.1535 inches. Wire used for lacing or as internal connecting wire within basket cells shall meet the same specifications described above for the mesh wire, except that it may be of lighter gauge with a minimum diameter after galvanization of 0.0866 inches and the zinc coating shall not be less than 0.70 oz./sq. ft. When a P.V.C. coating is specified, all wire used in the fabrication of the gabions and in the wiring operations during construction shall, after zinc coating have extruded onto it a coating of poly vinyl chloride. The coating shall be grey in color of nominal thickness 0.02165 inches and shall nowhere be less than 0.015 inches in thickness. It shall be capable of resisting deleterious effects of natural weather exposure, immersion in salt water and shall not show any material difference in its initial characteristics.

4.2 Stone Fill

All stone fill shall be approved by the Engineer and shall be of suitable quality to ensure durability. When the stone is subjected to five alterations of sodium sulfate soundness testing, in accordance with AASHTO T-104, the weighted percentage of loss shall not be more than twelve percent. The inclusion of objectionable quantities of shale, dirt, sand, clay, rock fines, and other deleterious material will not be permitted. Stone fill shall be of well-graded mixture with sizes ranging between 4 inches and 10 inches in diameter, based on U.S. Standard square mesh sieves. No stone shall have minimum dimension less than 4 inches. Stone fill material selected for use in the gabions shall meet the minimum in-place density specified on the plans.

4.3 Filter Cloth

All filter cloth shall meet the applicable requirements of Section 918.27, Sub-Section 27, of the Standard Specifications.

4.4 Filter Stone

All filter stone shall meet the applicable requirements of Grading Size 68 or 57. See the Standard Specifications section 903.22.

5.0 Construction

5.1 Clearing and Grubbing

Clearing and grubbing, removal of structures and obstructions, and excavation and undercutting shall be performed in accordance with the provisions of Sections 201, 202, and 203, respectively, of the Standard Specifications. Cost of these items, however, shall be included in the square foot price bid retaining walls as shown in contract plans.

5.2 Foundation Preparation

Foundation preparation for the gabions shall be made to the required depth below the finished surface and to such a width as to permit the proper installation of the gabions. Prior to wall construction, the top 12 inches of the foundation shall be compacted to at least 95% of maximum laboratory dry density as specified in AASHTO T 99. All soft and unsuitable material shall be removed and replaced with suitable material, which shall then be compacted. The finished subgrade shall be smooth and uniform, with no protruding debris or rock formations. A Size 57 stone may be required to obtain the smooth uniform surface and shall be in reasonably close conformity with the dimensions and designs shown on the plans or established by the Engineer. No gabions shall be constructed upon frozen foundation material.

5.3 Filter Cloth or Filter Stone

Upon final foundation preparation and acceptance by the Engineer, the filter cloth or filter stone shall be placed directly on the foundation at those locations shown on the plans or as directed by the Engineer. All end and side laps shall be a minimum of 18 inches for the filter cloth.

5.4 Assembly (Fabrication)

Gabions shall be fabricated in such a manner that the sides, ends, lid, and diaphragms can be assembled at the construction site into rectangular baskets. Gabions shall be of single unit construction, i.e., the base, lid, ends, and sides shall be either woven into a single unit or one edge of these members connected to the base section of the gabion in such a manner that strength and flexibility at the point of connection is at least equal to that of the mesh. Gabion units shall be equally divided, by diaphragms of the same mesh and gauge as the body of the gabions, into cells whose length does not exceed the horizontal width. The gabion shall be furnished with the necessary diaphragms secured in proper position on the base in such a manner that no additional tying at this juncture will be necessary. All perimeter edges of the mesh forming the gabion shall be securely selvaged so that the joints formed by tying the selvages have at least the same strength as the body of the mesh. Lacing wire or connecting wire shall be supplied in sufficient quantity for securely fastening all diaphragms and edges of the gabion.

5.5 Assembly (Field)

- 5.5.1 Empty gabion units shall be placed on the filter blanket when required on contract drawings and shall be assembled individually to the lines and grades indicated on the Plans or as directed by the Engineer, with the sides, ends, and diaphragms erected in such a manner to ensure the correct position. All adjoining empty gabion units must be connected by tie wire lacing along the perimeter of their contact surfaces in order to obtain a monolithic structure. Lacing of adjoining basket units shall be accomplished by continuous stitching with alternating single and double loops at intervals of not more than 5 inches. All lacing wire terminals shall be securely fastened. The use of expedient clip connections for this purpose or as final lid closing will not be permitted. After adjoining empty basket units are set to line and grade and common sides with adjacent units thoroughly laced, they shall be placed in tension and stretched to remove any kinks from the mesh and to a uniform alignment. The stretching of empty basket units shall be accomplished in such a manner as to prevent any possible unraveling and distortion.
- 5.5.2 Stone filling operations shall carefully proceed with placement by hand or machine so as not to damage galvanized wire coating, to assure a minimum of voids between the stones, to prevent damage to the underlying filter blanket, and to ensure the maintenance of alignment throughout the filling process. The maximum height from which the stone may be dropped into the basket units shall be 36 inches. Along all exposed faces, the outer layer of stone shall be carefully placed and arranged by hand to ensure a neat and compact appearance. The last layer of stone shall be leveled with the top of the gabions to allow for the proper closing of the lid and to provide an even surface that is uniform in appearance.
- 5.5.3 Lids shall be stretched tight over the stone fill using crowbars or lid closing tools until the lid meets the perimeter edges of the front and end panels. The lid shall then be tightly laced with tie wire along all edges, ends and internal cell diaphragms by continuous stitching with alternating single and double loops at intervals of not more than 5 inches. Special attention shall be given to see that all projections or wire ends are turned into the baskets. Where shown on the drawings or as directed by the Engineer, or where a complete gabion unit cannot be installed because of space limitations, the basket unit shall be cut, folded and wired together to suit existing site conditions. The mesh must be cleanly cut and the surplus mesh cut out completely or folded back and neatly wired to an adjacent gabion face. The assembling, installation, filling, lid closing, and lacing of the reshaped gabion units shall be carried out as specified above.

5.6 Backfill

Backfilling of the gabion wall shall follow erection as closely as possible and in no case should the height of the wall be greater than seven feet above the backfill. Underdrains, if required, shall be placed in accordance with the details shown on plans. Gabion walls backfill shall have a density of 100 pounds per cubic foot or as specified on contract plans and shall be compacted to at least 95 percent of the maximum laboratory dry density as defined in AASHTO T 99 to within one foot of the top of the wall. The top 12 inches shall be compacted to at least 100 percent of the maximum laboratory dry density. The backfill material shall consist of broken or crushed stone, gravel, sand, slag or other suitable coarse granular material to insure proper drainage. Shale, clay or cinders shall not be permitted as backfill material. Prior to placement, the backfill material must be approved by the Engineer. The Contractor shall furnish, install, operate, and maintain satisfactory dewatering system as required to maintain the site in a dry and workable condition so as to permit grading and compaction of the wall foundation and proper erection and backfill of the wall. These systems shall include all equipment and materials, and shall be continued as long as necessary. No separate measurement or payment will be made for dewatering or dewatering systems.

All backfill material shall be tested prior to use and at the established frequencies in the TDOT “Procedures for the Sampling and Testing, and Acceptance of Materials and Products (SOP 1-1)”.

5.7 Vertical Wall Tolerance

The overall vertical tolerance of the wall (plumbness from top to bottom) shall not deviate more than ½ inch per 10 feet of wall height from the contract drawings batter of the wall.

5.8 On Site Inspection

The quality of materials, the process of manufacture, and the finished members shall be subject to inspection and approval by the Engineer. Any gabions damaged prior to acceptance shall be repaired or reconstructed as directed by the Engineer. All costs of repairs or reconstruction shall be at the Contractor’s expense.

5.9 Final Cleanup

Final cleanup shall be performed in accordance with the requirements of Section 104, Sub-Section 11, of the Standard Specifications.

5.10 Equipment

All equipment necessary for the satisfactory performance of the construction of stone-filled gabions shall be approved by the Engineer before construction will be permitted to begin.

6.0 Method of Measurement

Gabion walls will be measured by the square foot of surface area of the wall face..

7.0 Basis of Payment

Payment for gabion walls will be as outlined on the contract drawings and shall be full compensation for pre-construction engineering, preparation of plans and working drawings, excavation, sheeting, shoring, foundation preparation, drainage, filter blanket, wire mesh baskets, tying, stone fill, erection of units, miscellaneous hardware, select backfill, presplitting, shaping of cuts, bituminous fiberboard and all miscellaneous materials and labor required for complete approved installation of gabions.

Additional area of wall required due to unforeseen conditions or other reasons and approved by the Engineer will be paid for on the basis of the unit price bid. If required for retaining wall protection against vehicle impact, the cost of the barrier wall and end terminals shall be included in the square foot cost of the wall.

F. Segmental, Precast Facing Mechanically Stabilized Earth (MSE) Wall

1.0 Description

This section covers the design, working drawings, materials, fabrication, construction, measurement, and payment for Mechanically Stabilized Earth (MSE) Walls. The scope of work of the wall erection includes all grading necessary for wall construction, undercutting and backfilling of weak surficial zones, compaction of the wall foundation, general and local dewatering as required for proper execution of the work, construction of leveling pads, erection of precast panels, placement of soil reinforcing devices, and placement and compaction of special embankment backfill within the reinforced volume. The scope of work also includes furnishing and placing precast or cast-in-place concrete coping and cast-in-place precast concrete traffic barrier on the top or face of the wall if these items are shown on the plans. The wall foundation shall include all area underlying the leveling pad and the reinforced volume. All other items included in the construction of the MSE Wall not specifically mentioned herein shall conform to the applicable sections of the *Tennessee Department of Transportation Standard Specifications for Road and Bridge Construction*, henceforth referred to as the Standard Specifications, and the current *AASHTO Standard Specifications for Highway Bridges with interims*, henceforth referred to as AASHTO. The architectural treatment and/or texture finish of the MSE walls shall be in accordance with the contract plan details.

2.0 Design Criteria

The current *AASHTO Standard Specifications for Highway Bridges with interims* and publication no. FHWA-NHI-00-043, *Mechanically Stabilized Earth Walls and Reinforced Soil Slopes Design and Construction Guidelines*, shall be used as the basis for design.

3.0 Submittals

Requirements for submittals are outlined in Chapter I, Section 4.0, Requirements for Contractor/Supplier Prepared Design and Plans.

4.0 Materials

General - The Contractor shall make arrangements to purchase or manufacture the facing elements, reinforcing mesh or strips, attachment devices, joint filler, and all other necessary components. Materials not conforming to this section of the Standard Specifications or from sources not listed in the contract document shall not be used without written consent from the Engineer.

Out-of-state producers shall provide documentation of material quality before the manufacture of any pre-cast products (i.e. aggregate quality reports, cement/steel mill test reports, etc

- 4.1 Reinforced Concrete Facing Panels - The panels shall be fabricated in accordance with the TDOT Procedure for the “Manufacture and Acceptance of Pre-cast Concrete Drainage Structures, Noise Wall panels, and Retaining wall panels.”
 - 4.1.1 Acceptability of the precast units will be determined on the basis of compressive strength tests, production tolerances, and visual inspection. The Contractor, or the supplier, shall furnish facilities and perform all necessary sampling and testing in an expeditious and satisfactory manner as directed by the Engineer.
 - 4.1.2 The Portland cement shall be types 1, 2, or 3 and shall conform to the requirements of AASHTO M 85 (ASTM C 150). Concrete for precast panels shall be Class D (4000 psi) as specified in Section 604 of the TDOT Standard Specifications. Admixtures containing chlorides shall not be used.
 - 4.1.3 The panels shall be cast using steel forms. The front face of the panel (face exposed to view when installed in the wall) shall be cast against a steel form or architectural form liner. The back face is to be float finished. The concrete in each panel shall be placed without interruption and shall be consolidated by the use of an approved vibrator, supplemented by such hand tamping as may be necessary to force the concrete into the corners of the forms and prevent the formation of stone pocket or cleavage planes. Clear form oil of the same type shall be used throughout the casting operation.
 - 4.1.4 Unless otherwise indicated on the plans or elsewhere in the Standard Specifications, the concrete surface for the front face shall have a Class 1 finish as defined by Section 8.12 of AASHTO, Division II, and for the rear face a uniform surface finish. The rear face of the panel shall be float finished sufficiently to eliminate open aggregate pockets and surface distortions in excess of 1/4 inch. The panels shall be cast on a flat area. The strips or other galvanized attachment devices shall not contact or be attached to the face panel reinforcement steel.
 - 4.1.5 Curing and forms removal shall be in accordance with the requirements of Section 604.20 and 604.24 of the Standard Specifications, unless otherwise approved by the Engineer. The forms shall remain in place until they can be removed without damage to the panel.

- 4.1.6 The units shall be fully supported until the concrete reaches a minimum compressive strength of 1000 psi. The units may be shipped after reaching a minimum specified compressive strength of 4000 psi. TDOT will verify products before shipment in accordance with the TDOT Procedure for the “Manufacture and Acceptance of Pre-cast Concrete Drainage Structures, Noise Wall panels, and Retaining wall panels”. If products are manufactured out of state, TDOT may verify at the project site PRIOR to the placement of the units. The Contractor, or producer, shall notify the Regional Materials and Tests Division that products need to be verified.
- 4.1.7 Marking - The date of manufacture, the production lot number, and the piece mark shall be clearly scribed on an unexposed face of each panel.
- 4.1.8 Handling, Storage, and Shipping - All units shall be handled, stored, and shipped in such a manner as to eliminate the dangers of chipping, discoloration, cracks, fractures, and excessive bending stresses. Panels damaged during handling or storage at the casting plant, shall be repaired at the plant, as directed by the Engineer. Any panels damaged during handling, storing, or shipping may be rejected upon delivery at the option of the Engineer. Panels in storage shall be supported in firm blocking located immediately adjacent to embedded connection devices to avoid bending the connection devices.
- 4.1.9 Tolerances - All units shall be manufactured within the following tolerances:
1. Panel Dimensions - Position panel connection devices within 1 inch, except for all other dimensions within 3/16 inch.
 2. Panel Squareness - Squareness as determined by the difference between the two diagonals shall not exceed 1/2 inch.
 3. Angular distortion with regard to the height of the panel shall not exceed 3/16 inch in 5 feet.
 4. Panel Surface Finish - Surface defects on smooth formed surfaces measured over a length of 5 feet shall not exceed 1/8 inch. Surface defects on the textured-finish surfaces measured over a length of 5 feet shall not exceed 5/16 inch.
- 4.1.10 Steel - In accordance with the Standard Specifications.

- 4.1.11 Compressive Strength - Acceptance of the concrete panels, with respect to compressive strength, will be determined on the basis of production lots. A production lot is defined as a group of panels that will be represented by a single compressive strength sample and will consist of a single day's production as defined in the certify in accordance with the TDOT Procedure for the "Manufacture and Acceptance of Pre-cast Concrete Drainage Structures, Noise Wall panels, and Retaining wall panels".

During the production of the concrete panels, the Engineer will sample the concrete in accordance with AASHTO T 141 (ASTM C 172). A single compressive strength sample, consisting of a minimum of six (6) cylinders, will be randomly selected for every production lot.

Cylinders for compressive strength tests shall be prepared in accordance with AASHTO T 23 (ASTM C 31) on 6" x 12" or 4" x 8" specimens. For every compressive strength sample, a minimum of two (2) cylinders will be cured in the same manner as the panels and tested for acceptance no later than twenty-eight (28) days. The average compressive strength of these two cylinders, when tested according with AASHTO T 22 (ASTM C 39), will determine the compressive strength of the production lot..

If the Contractor wishes to remove forms or ship the panels prior to 28 days, a minimum of two (2) additional cylinders will be cured in the same manner as the panels. The average compressive strength of these cylinders when tested in accordance with AASHTO T 22, will determine whether the forms can be removed and the panels are acceptable.

Acceptance of a production lot will be made if the compressive strength test result is greater than or equal to 4,000 psi when tested for acceptance no later than 28 days.

In the event that a production lot fails to meet the specified compressive strength requirements, the production lot shall be rejected. Such rejection shall prevail unless the manufacturer, at their own expense, obtains and submits cores for testing and the results show that the strength and quality of the concrete placed within the panels of the production lot is acceptable. The cores shall be taken from the panels within the production lot and tested in accordance with the specifications of AASHTO T 24 (ASTM C 42). Two cores per each cylinder that failed will be required. In addition, any or all of the following defects shall be sufficient cause for rejection:

1. Defects that indicate imperfect molding.
2. Defects indicating honeycombing or open texture concrete.
3. Defects in the physical characteristics of the concrete such as cracked or severely chipped panels.
4. Color variation on front face of panel due to excess form oil or other reasons.
5. Damage due to handling, storing or shipping.

The Engineer shall determine whether spalled, honeycombed, chipped or otherwise defective concrete shall be repaired or rejected. Repair of concrete, if allowed, shall be done with a TDOT approved cementitious polymer patching mortar in a manner satisfactory to the Engineer. Repair to concrete surfaces that will be exposed to view after completion of construction must be approved by the Engineer.

4.2 Soil Reinforcing and Attachment Devices - All reinforcing and attachment devices shall be shop fabricated and carefully inspected to ensure they are true to size and free from defects that may impair their strength and durability.

4.2.1 Reinforcing Strips - Reinforcing strips shall be hot rolled from bars to the required shape and dimensions. Their physical and mechanical properties shall conform to either AASHTO M 183 (ASTM A 36) or AASHTO M 223 (ASTM A 572) grade 65 or equal. Galvanization shall conform to the minimum requirements or AASHTO M 111 (ASTM A 123).

4.2.2 Tie Strips - The tie strips shall be shop- fabricated of a hot rolled steel conforming to the minimum requirements of ASTM 570, Grade 50 or equivalent. Galvanization shall conform to AASHTO M 111 (ASTM A 123). Tie straps may be partially bent before shipment to the precast yard. Minimum bending radius shall be one inch. Final bending may be accomplished at the precast yard.

4.2.3 Reinforcing Mesh - Reinforcing mesh shall be shop fabricated of cold drawn steel wire conforming to the minimum requirements of AASHTO M 32 (ASTM A 82) and shall be welded into the finished mesh fabric in accordance with AASHTO M 55 (ASTM A 185). Galvanization shall be applied after the mesh is fabricated and conform to the minimum requirements of AASHTO M 111 (ASTM A 123).

- 4.2.4 Fasteners - Fasteners shall be high strength hexagonal cap screw bolts and nuts conforming to AASHTO M 164 (ASTM A 325). Galvanizing fastener elements, including washers, shall be in accordance with AASHTO M 232 (ASTM A 153). Bolts and nuts nominal diameter will be shown in the plans and supplied in accordance with the fasteners as specified previously.
- 4.2.5 Steel Strap Connections - The steel strap connection bar and plate shall meet the same requirements as the reinforcing and tie strips specified above. Bolts, nuts, and washers shall conform to the requirements for the fasteners specified above. Coatings for connecting devices shall be as specified below.
- 4.2.6 Clevis Loop and Mesh Loop - Clevis loops and mesh loops shall be fabricated of cold drawn steel wire conforming to the requirements of AASHTO M 32 (ASTM A 82) and welded in accordance with AASHTO M 55 (ASTM A 185) and shall develop a minimum stress of $0.9 F_y$.
- 4.2.7 Connector Bar - Connector bar shall be fabricated of cold drawn steel wire conforming to the requirements of AASHTO M 32 (ASTM A 82).

Holes for bolts shall be punched in the location shown. Surfaces resulting from punching holes for bolts shall be galvanized in accordance with AASHTO M 111 (ASTM A 123). Those parts of the connecting devices which are threaded shall be galvanized in accordance with AASHTO M 232 (ASTM A 153). Alignment pins are to be hot dip galvanized.

All connecting devices shall be to the dimensions shown on the plans. Connecting members and soil reinforcement devices shall be assembled prior to galvanization. All connecting devices shall be true to size and free from defects that may impair their strength or durability.

Any damage sustained to any part of the connecting devices, bolts or reinforcing devices during any phase of fabrication, storage or erection shall be repaired to the satisfaction of the Engineer at no increase in contract cost.

- 4.3 Geosynthetic Reinforcement Material - Where geosynthetic reinforcements are used for the construction of MSE walls the following requirements shall apply:

- 4.3.1 Geotextiles and Thread for Sewing - Woven or nonwoven geotextiles shall consist only of long chain polymeric filaments or yarns formed into a stable network such that the filaments or yarns retain their position relative to each other during handling, placement, and design service life. At least 95 percent by weight of the long chain polymer shall be polyolefin or polyester. The material shall be free of defects and tears. The geotextile shall conform as a minimum to the properties indicated for Separation, Medium Survivability indicated under AASHTO T 288. The geotextile shall be free from any treatment or coating that might adversely alter its physical properties after installation.
- 4.3.2 Geogrids - The geogrid shall be a regular network of integrally connected polymer tensile elements with aperture geometry sufficient to permit significant mechanical interlock with the surrounding soil or rock. The geogrid structure shall be dimensionally stable and able to retain its geometry under manufacture, transport and installation.
- 4.3.3 Required Properties - The specific geosynthetic material(s) shall be preapproved by the Department and shall have certified long-term strength (T_{al}) as determined by:
1. Long-Term strength (T_{al}) based on $T_{al} = T_{ULT} / (RF_D) * (RF_{ID}) * (RF_{CR})$ where RF_{CR} is developed from creep tests performed in accordance with ASTM D 5262, RF_{ID} obtained from site installation damage testing and RF_{ID} from hydrolysis or oxidative degradation testing extrapolated to 75 or 100 year design life.
 2. Ultimate Strength (T_{ULT}) based upon minimum average roll values (MARV) (lb/ft), ASTM D4595.
 3. Pullout Resistance Factor developed in accordance with chapter 3 of FHWA-SA-96-071.
- 4.3.4 Certification - The Contractor shall submit a manufacturer's certification that the geosynthetics supplied meet the respective index criteria set when the geosynthetic was approved by the Department, measured in full accordance with all test methods and standards specified and as set forth in this document.

The manufacturer's certificate shall state that the furnished geosynthetic meets the requirements of this document as evaluated by the manufacturer's quality control program. The certificates shall be attested to by a person having legal authority to bond the manufacturer. In case of dispute over validity of value, the Engineer can require the Contractor to supply test data from a

Department approved laboratory to support the certified values submitted.

- 4.3.5 **Manufacturing Quality Control:** The geosynthetic reinforcement shall be manufactured with a high degree of quality control. The manufacturer is responsible for establishing and maintaining a quality control program to ensure compliance with the requirements of this document. The purpose of the QC testing program is to verify that the reinforcement geosynthetic being supplied to the project is representative of the material used for performance testing and approval by the Department.

Conformance testing shall be performed as part of the manufacturing process and may vary for each type of product. As a minimum, the following index tests shall be considered as applicable for an acceptable QA/QC program:

Property	Test Procedure
Specific Gravity (HDPE only)	ASTM D 1505
Wide Width Tensile	ASTM D 4595; GRI:GG1
Melt Flow (HDPE and PP only)	ASTM D 1238
Intrinsic Viscosity (PET only)	ASTM D 4603
Carboxyl End Group (PET only)	ASTM D 2455

- 4.3.6 **Sampling, Testing, and Acceptance -** Sampling and conformance testing shall be in accordance with ASTM D 4354. Conformance testing procedures shall be as established under 4.3.5. Geosynthetic product acceptance shall be based on ASTM D 4759.

The quality control certificate shall include:

- Roll numbers and identification
- Sampling procedures
- Result of quality control tests, including a description of test methods used

- 4.3.7 **Select Granular Backfill Material -** The backfill material shall conform to the requirements set forth in section 4.5 except that the maximum size of the backfill shall be 3/4 inch, unless full scale installation damage tests are conducted in accordance with ASTM D 5818.

- 4.4 **Joint Materials -** Installed to the dimensions and thicknesses in accordance with the plans or approved shop drawings.

- 4.4.1 If required, provide flexible foam strips for filler for vertical joints between panels, and in horizontal joints where pads are used, where indicated on the plans.
 - 4.4.2 Provide in horizontal joints between panels preformed EPDM rubber pads conforming to ASTM D 2000 for 4AA, 812 rubbers, neoprene elastomeric pads having a Durometer Hardness of 55 ± 5 , or high density polyethylene pads with a minimum density of 59 lb/ft^3 in accordance with ASTM D 1505.
 - 4.4.3 Cover all joints between panels on the back side of the wall with a geotextile meeting the minimum requirements for filtration applications as specified by AASHTO M 288. The minimum width and lap shall be 12 inches. Adhesive used to attach the filter fabric to the back of the panels shall be approved by the wall supplier.
- 4.5 Select Granular Backfill Material - All backfill material used in the Mechanically Stabilized Earth structure volume, as shown on the plans, shall be reasonably free (maximum of 0.1%) from organic and otherwise deleterious materials, and it shall be approved by the Engineer prior to use. The material shall conform to the following gradation limits and be tested at the established frequencies in the TDOT “Procedures for the Sampling and Testing, and Acceptance of Materials and Products (SOP 1-1)”. The Contractor shall also provide test data from an approved laboratory certifying that the material meets the following:

4.5.1 Gradation as determined by AASHTO T 27.

SIEVE SIZE	PERCENT PASSING
4 Inches	100
3/8 Inch	0-75
No. 4	0-25
No. 8	0-10
No. 16	0-5

Note: Size Nos. 1 through 78 as listed in order of Table 1 Standard Sizes of Processed Aggregate in Section 903.22 of Standard Specifications meet the above gradation requirements.

- 4.5.2 In addition, the backfill must conform to all of the following requirements:
- 1. Soundness - The material shall be substantially free from shale or other soft, poor durability particles. The material shall have a sodium sulfate loss of less than 12 percent after

five (5) cycles determined in accordance with AASHTO T 104.

2. The Plasticity Index (P.I.), as determined by AASHTO T 90, shall not exceed 6. (Note: with the above gradation this requirement would be no longer applicable.)
3. The material shall exhibit an angle of internal friction of not less than 34 degrees as determined by the standard direct shear test AASHTO T 236 on the portion finer than the No. 4 sieve, using a sample of the material compacted to 95 percent of AASHTO T 99. No testing is required for backfills where 80 percent of sizes are greater than 3/8 inch.
4. Electrochemical requirements - The backfill shall meet the following criteria:

REQUIREMENTS	TEST METHOD
ph= 5-10	AASHTO T 289 – 91
Resistivity > 3000 ohm centimeters ¹	AASHTO T 288 – 91
Chlorides < 100 parts per million	AASHTO T 291 – 91
Sulfates < 200 parts per million	AASHTO T 290 – 91
Organic Content < 1%	AASHTO T 267 – 86

1. If the resistivity is greater or equal to 5000 ohm centimeters the chloride and sulfates requirements may be waived.

5. Unit weight- The unit weight of the backfill material (at optimum condition) shall meet the requirements of the approved shop drawings or plans.
- 4.6 Concrete Leveling Pad, Traffic Barrier and Coping - The concrete shall conform to the requirements of the Standard Specifications for Class A concrete.
 - 4.7 Acceptance of Material - The Contractor shall furnish the Engineer a Certificate of Compliance certifying the above materials comply with the applicable contract specifications. A copy of all test results performed by the Contractor necessary to assure contract compliance shall be furnished to the Engineer.

Acceptance will be based on the TDOT “Procedures for the Sampling and Testing, and Acceptance of Materials and Products (SOP 1-1)”.

5.0 Construction

- 5.1 Wall Excavation - Unclassified excavation shall be in accordance with the requirements of the Standard Specifications and in reasonably close conformity with the limits and construction lines shown on the plans. Temporary excavation support as required shall be the responsibility of the Contractor.
- 5.2 Foundation Preparation - The foundation for the MSE wall shall be graded level for a minimum width equal to the width of the reinforced volume and leveling pad plus one (1) foot, or as shown on the plans, using the top of the leveling pad as the grade elevation. Prior to wall construction, the foundation shall be compacted to 95 percent of optimum density, as directed by the Engineer. Any foundation soils found to be unsuitable shall be removed as directed by the Engineer and replaced with select granular backfill material compacted to 95 percent of AASHTO T 99. At each panel foundation level, a precast reinforced or a cast-in-place unreinforced concrete leveling pad of the type shown on the plans shall be provided. The concrete shall be Class “A” concrete with compressive strength of 3000 psi (28 day strength). The leveling pad shall be cured a minimum of 12 hours before placement of wall panels.
- 5.3 Wall Erection - Where a proprietary wall system is used, a field representative shall be available during the erection of the wall to assist the fabricator, Contractor, and Engineer. If there is more than one wall of the same type on the project, this requirement will apply to construction of the initial wall only. After construction of the initial wall, the representative will be available on an as-needed basis, as requested by the Engineer, during construction of the remainder of the walls. Wall erection shall be in conformance with the latest edition of the MSE wall construction manual as published by the wall supplier. For erection, panels are handled by means of a lifting device set into the upper edge of the panel. Precast concrete panels shall be placed such that a final vertical face will be obtained.

It shall be the responsibility of the Contractor to consult with the designer/supplier and to utilize the proper methods necessary to achieve a vertical face for the final wall. Panels should be placed in successive horizontal lifts as backfill placement proceeds. As backfill material is placed behind the panels, the panels shall be maintained in position by means of temporary wedges or bracing according to the wall supplier’s recommendations. External bracing shall also be required for this initial lift. The wedges shall remain in place until the fourth layer of panels is

placed, at which time the bottom layer of wedges shall be removed. Each succeeding layer of wedges shall be removed as the succeeding panel layers are placed. When the wall is completed, all wedges shall be removed. No wedges shall be used as a means of leveling panels on leveling pads. Wedges placed below the ground line on the front face of the wall shall be removed before this area is backfilled.

Tolerances and alignment shall be as follows:

1. Horizontal and vertical joint openings between panels shall be uniform. The maximum allowable offset in any panel joint shall be 3/4 inch.
2. Vertical tolerance (plumbness) and horizontal alignment tolerances as the wall is constructed shall not exceed 3/4 inch when measured along a 10 foot straightedge.
3. The overall vertical tolerance of the wall (plumbness from top to bottom) in its final position shall not exceed 3/4 inch per 10 feet of wall height.

Cast-in-place concrete shall be placed on top of wall panels to allow precast coping elements on top of the wall to be brought to proper grade.

Prior to placing any select backfill material on any soil reinforcement device, all connections to the panels shall be completed.

- 5.4 Backfill Placement - Backfill placement shall closely follow the erection of each lift of panels. Backfill shall be placed in such a manner as to avoid any damage or disturbance to the wall materials including panels, soil reinforcements, and connections, or misalignment of the facing panels or reinforcing elements. Any wall materials which may become damaged or disturbed during backfill placement, or due to wall settlement prior to completion of the project shall be either removed and replaced at the Contractor's expense or corrected, as directed by the Engineer. Any misalignment or distortion of the wall facing panels due to placement of backfill outside the limits of this section shall be corrected, as directed by the Engineer at the Contractor's expense. Backfill placement methods near the facing shall assure that no voids exist directly beneath the reinforcing elements.

Backfill shall be compacted to 95 percent of the maximum density as determined by AASHTO T 99. When the backfill supports a spread footing of a bridge or other structural load, the top 5 feet shall be compacted to 100 percent of the maximum density. For backfills containing more than 30 percent retained on the 3/4 inch sieve, a method compaction consisting of a minimum of 4 passes of a heavy roller shall be used.

The moisture content of the backfill material prior to and during compaction shall be uniformly distributed throughout each layer. Backfill materials shall be placed at a moisture content not more than 2 percentage points less than or equal to the optimum moisture content. Backfill material with a placement moisture content in excess of the optimum moisture content shall be removed and reworked until the moisture content is uniformly acceptable throughout the entire lift. The optimum moisture content shall be determined in accordance with AASHTO T 99.

At each soil reinforcement device level, backfill shall be compacted to the full length of reinforcement devices and be sloped to drain away from the wall before placing and attaching the next layer of reinforcement devices. The compacted backfill shall be level with the connecting device before the reinforcement device can be connected. Compaction within three feet of the back face of the wall facing panel shall be achieved with at least three (3) passes of a light weight mechanical tamper, roller, or vibratory system.

Unless otherwise indicated on the plans or directed by the Engineer, soil reinforcement devices shall be placed at 90 degrees to the face of the wall. The maximum lift thickness before compaction shall be ten (10) inches and shall closely follow panel erection. The Contractor shall decrease this lift thickness, if required, to obtain the specified density.

At the end of each day's operation, the Contractor shall slope the last level of backfill away from the wall facing to rapidly direct runoff or rainwater away from the wall face. In addition, the Contractor shall not allow surface runoff from adjacent areas to enter the wall construction site.

6.0 Method of Measurement

The method of measurement shall be square foot area of the wall face, measured from the top of the footing to the top of the wall excluding any appurtenances.

7.0 Basis of Payment

The mechanically stabilized earth wall, complete in place and accepted, shall be paid for at the contract square foot bid price. The bid price for walls shall include as required: all costs for grading and compaction of the wall foundation, footing excavation, installation of foundation improvements as required in the Wall Concept Drawings such as undercutting to certain elevations or materials and replacing with a prescribed select material, installation of geo-structural elements such as Geopiers, stone columns or other foundation improvement methods, pre-splitting, cast-in-place or precast coping, cast-in-place level up concrete for top panels, prefabricated modular blocks, reinforcement strips or mesh, tie strips or rods, fasteners, connectors, joint materials, leveling pads, footings, sheeting, shoring, select granular material in the reinforced mass, backfilling, hardware, filter cloth, reinforcement steel, and all miscellaneous material and labor required for the

complete installation of the wall. No increase in unit price will be paid for increases in wall height less than or equal to 10 feet. Wall height increases greater than 10 feet will be paid for by supplemental agreement. If required for retaining wall protection against vehicle impact, the cost of the barrier wall and end terminals shall be included in the square foot cost of the wall.

G. Prefabricated Modular Block Facing Mechanically Stabilized Earth (MSE) Wall

1.0 Description

This section covers the design, working drawings, materials, fabrication, construction, measurement, and payment for Mechanically Stabilized Earth (MSE) Walls with Concrete Modular Block (MBW) facing and unit fill. The scope of work of the wall erection includes all grading necessary for wall construction, undercutting and backfilling of weak surficial zones, compaction of the wall foundation, general and local dewatering as required for proper execution of the work, construction of leveling pads, erection of modular block facing, placement of soil reinforcing devices, and placement and compaction of special embankment backfill within the reinforced volume. The scope of work also includes furnishing and placing precast or cast-in-place concrete coping and cast-in-place precast concrete traffic barrier on the top or face of the wall if these items are shown on the plans. The wall foundation shall include all area underlying the leveling pad and the reinforced volume. All other items included in the construction of the MSE Wall not specifically mentioned herein shall conform to the applicable sections of the *Tennessee Department of Transportation Standard Specifications for Road and Bridge Construction*, henceforth referred to as the Standard Specifications, and the current *AASHTO Standard Specifications for Highway Bridges* with latest revisions. The architectural treatment and/or texture finish of the MSE walls shall be in accordance with the contract plan details.

2.0 Design Criteria

The current *AASHTO Standard Specifications for Highway Bridges* and publication no. FHWA-NHI-00-043, *Mechanically Stabilized Earth Walls and Reinforced Soil Slopes Design and Construction Guidelines*, shall be used as the basis for design.

3.0 Submittals

Requirements for submittals are outlined in Chapter I, Section 4.0, Requirements for Contractor/Supplier Prepared Design and Plans.

4.0 Materials

General - The contractor shall make arrangements to purchase or manufacture the facing elements, reinforcing mesh or strips, attachment devices, joint filler, and all other necessary components. Materials not conforming to this section or from sources not listed in the contract document shall not be used without written consent from the Engineer.

- 4.1 Concrete Modular Block Facing - The concrete modular blocks shall be either hollow or solid concrete structural retaining wall units, machine made from Portland cement, water, and mineral aggregates with or

without the inclusion of other materials. The units are intended for use in the construction of mortarless, modular block retaining (MBW) walls.

4.1.1 Cementitious Materials - Materials shall conform to the following:

- 4.1.1.1 Portland Cement - AASHTO M 85 (ASTM C 150).
- 4.1.1.2 Blended Cements – Type IP -AASHTO M 240 (ASTM C 595).
- 4.1.1.3 Pozzolans – Class C or Class F fly ash -AASHTO M 295 (ASTM C 618).
- 4.1.1.4 Blast Furnace Slag Cement – grade 100 or 120- AASHTO M 302 (ASTM C 989).

4.1.2 Aggregates - Aggregates shall conform to the following specifications, except that grading requirements shall not necessarily apply:

- 4.1.2.1 Normal Weight Aggregates – TDOT Standard Specification sections 903.01 and 903.03.
- 4.1.2.2 Lightweight Aggregates - TDOT Standard Specification section 903.19.

4.1.3 Other Constituents - Air-entraining agents, coloring pigments, integral water repellants, finely ground silica, and other constituents shall be previously established as suitable for use in concrete MBW units shall conform to applicable AASHTO Standards or, shall be shown by test or experience to be not detrimental to the durability of MBW units or any material customarily used in masonry construction.

4.1.4 Physical Requirements. Prior to delivery to the work site, the units shall conform to the following physical requirements:

1. Minimum required compressive strength = 4,000 psi (Average 3 coupons)
2. Minimum required compressive strength = 3,500 psi (Individual coupon)
3. Maximum water absorption = 5%
4. Maximum number of blocks per lot = 2,000

Also, prior to delivery, TDOT will conduct verification testing on the modular blocks in accordance with the TDOT “Procedures for

the Sampling and Testing, and Acceptance of Materials and Products (SOP 1-1)

If products are manufactured out of state, TDOT may verify at the project site PRIOR to the placement of the units. The Contractor, or producer, shall notify the Regional Materials and Tests Division that products need to be verified.

4.1.5 Tolerances. Blocks shall be manufactured within the following tolerances:

4.1.5.1 The length and width of each individual block shall be within $\approx 1/8$ inch of the specified dimension. Hollow units shall have a minimum wall thickness of 1-1/4 inch.

4.1.5.2 The height of each individual block shall be within $\approx 1/16$ inch of the specified dimension.

4.1.5.3 When a broken face finish is required, the dimension of the front face shall be within ≈ 1 inch of the theoretical dimension of the unit.

4.1.5.4 Finish and Appearance. All units shall be sound and free of cracks or other defects that would interfere with the proper placing of the unit or significantly impair the strength or permanence of the construction. Minor cracks (e.g. no greater than 1/32 inch in width and no longer than 25 % of the unit height) incidental to the usual method of manufacture or minor chipping resulting from shipment and delivery, are not grounds for rejection.

The face or faces of units that are to be exposed shall be free of chips, cracks or other imperfections when viewed from a distance of 30 feet under diffused lighting. Up to five (5) percent of a shipment may contain slight cracks or small chips not larger than 1 inch.

Color and finish shall be as shown on the plans and shall be erected with a running bond configuration.

4.1.5.5 If pins are required to align MBW units, they shall consist of a nondegrading, polymer or galvanized steel and be made for the express use with the MBW units supplied.

4.1.5.6 Cap units shall be cast to or attached to the top MBW units in strict accordance with the manufacturer's requirements and the adhesive manufacturer's recommended procedures. The Contractor shall provide a written 10 year warranty, acceptable to the Department, that the integrity of the materials used to attach the cap blocks will preclude separation and displacement of the cap blocks for the warranty period.

4.1.6 Sampling and Testing. Acceptance of the concrete block with respect to compressive strength and absorption, will be determined on a lot basis. The lot will be randomly sampled in accordance with ASTM C 140. Compressive strength and absorption tests shall be performed by the manufacturer and submitted to the Department. Compressive strength test specimens shall be cored or shall conform to the saw-cut coupon provisions of section 6.2.4 of ASTM C 140. Blocks represented by test coupons that do not reach an average compressive strength of 4,000 psi or an individual strength of 3500 psi, or have less than 5 % absorption will be rejected.

4.1.7 Rejection. Blocks shall be rejected because of failure to meet any of the requirements specified above. In addition, any or all of the following defects shall be sufficient cause for rejection.

1. Defects that indicate imperfect molding.
2. Defects indicating honeycomb or open texture concrete.
3. Cracked or severely chipped blocks.
4. Color variation on front face of block due to excess form oil or other reasons.

Blocks may also be rejected if TDOT verification test results do not comply with the requirements specified above.

4.2 Unit Fill - The unit fill and drainage aggregate shall be a well graded crushed stone or granular fill meeting the following gradation:

U.S. Sieve Size	Percent Passing
1 inch	100-75
3/4 inch	50-75
No. 4	0-60

No. 40	0-50
No. 200	0-5

- 4.3 Geosynthetic Reinforcement Material - The following requirements shall apply for geosynthetic reinforcement material:
- 4.3.1 Geotextiles and Thread for Sewing - Woven or nonwoven geotextiles shall consist only of long chain polymeric filaments or yarns formed into a stable network such that the filaments or yarns retain their position relative to each other during handling, placement, and design service life. At least 95 percent by weight of the long chain polymer shall be polyolefin or polyester. The material shall be free of defects and tears. The geotextile shall conform as a minimum to the properties indicated for Separation, Medium Survivability indicated under AASHTO T 288. The geotextile shall be free from any treatment or coating that might adversely alter its physical properties after installation.
- 4.3.2 Geogrids - The geogrid shall be a regular network of integrally connected polymer tensile elements with aperture geometry sufficient to permit significant mechanical interlock with the surrounding soil or rock. The geogrid structure shall be dimensionally stable and able to retain its geometry under manufacture, transport and installation.
- 4.3.3 Required Properties - The specific geosynthetic material(s) shall be pre-approved by the Department and shall have certified long-term strength (T_{al}) as determined by:
1. Long-Term strength (T_{al}) based on $T_{al} = T_{ult}/(RF_D)*(RF_{ID})*(RF_{CR})$ where RF_{CR} is developed from creep tests performed in accordance with ASTM D 5262, RF_{ID} obtained from site installation damage testing and RF_{ID} from hydrolysis or oxidative degradation testing extrapolated to 75 or 100 year design life.
 2. Ultimate Strength (T_{ULT}) based upon minimum average roll values (MARV) (lb/ft), ASTM D4595.
 3. Pullout Resistance Factor developed in accordance with chapter 3 of FHWA-SA-96-071.
- 4.3.4 Certification - The Contractor shall submit a manufacturer's certification that the geosynthetics supplied meet the respective index criteria set when the geosynthetic was approved by the Department, measured in full accordance with all test methods and standards specified and as set forth in this section of the TDOT

Earth Retaining Structures Manual. The manufacturer's certificate shall state that the furnished geosynthetic meets the requirements of this document as evaluated by the manufacturer's quality control program. The certificates shall be attested to by a person having legal authority to bond the manufacturer. In case of dispute over validity of values, the Engineer can require the Contractor to supply test data from a Department approved laboratory to support the certified values submitted.

- 4.3.5 Manufacturing Quality Control: The geosynthetic reinforcement shall be manufactured with a high degree of quality control. The manufacturer is responsible for establishing and maintaining a quality control program to ensure compliance with the requirements of the TDOT Earth Retaining Structures Manual. The purpose of the QC testing program is to verify that the geosynthetic being supplied to the project is representative of the material used for performance testing and approval by the Department.

Conformance testing shall be performed as part of the manufacturing process and may vary for each type of product. As a minimum the following index tests shall be considered as applicable for an acceptable QA/QC program:

<u>Property</u>	<u>Test Procedure</u>
Specific Gravity (HDPE only)	ASTM D 1505
Wide Width Tensile	ASTM D 4595; GRI:GG1
Melt Flow (HDPE and PP only)	ASTM D 1238
Intrinsic Viscosity (PET only)	ASTM D 4603
Carboxyl End Group (PET only)	ASTM D 2455

- 4.3.6 Sampling, Testing, and Acceptance - Sampling and conformance testing shall be in accordance with ASTM D 4354. Conformance testing procedures shall be as established under section 4.3.5. Geosynthetic product acceptance shall be based on ASTM D 4759.

The quality control certificate shall include:

1. Roll numbers and identification
2. Sampling procedures
3. Result of quality control tests, including a description of test methods used.

- 4.3.7 Select Granular Backfill Material - The backfill material shall conform to the requirements set forth in section 4.5 except that the

maximum size of the backfill shall be 3/4 inch, unless full scale installation damage tests are conducted in accordance with ASTM D 5818.

All backfill material shall be tested prior to use and at the established frequencies in the TDOT “Procedures for the Sampling and Testing, and Acceptance of Materials and Products (SOP 1-1)”.

- 4.4 Soil Reinforcing and Attachment Devices - Where steel reinforcing and attachment devices are used in the construction of the MSE wall the following requirements shall apply.
 - 4.4.1 Reinforcing Strips - Reinforcing strips shall be hot rolled from bars to the required shape and dimensions. Their physical and mechanical properties shall conform to either AASHTO M 183 (ASTM A 36) or AASHTO M 223 (ASTM A 572) grade 65 or equal. Galvanization shall conform to the minimum requirements or AASHTO M 111 (ASTM A 123).
 - 4.4.2 Tie Strips - The tie strips shall be shop-fabricated of a hot rolled steel conforming to the minimum requirements of ASTM A 570, Grade 50 or equivalent. Galvanization shall conform to AASHTO M 111. Tie straps may be partially bent before shipment to the precast yard. Minimum bending radius shall be one inch. Final bending may be accomplished at the precast yard.
 - 4.4.3 Reinforcing Mesh - Reinforcing mesh shall be shop fabricated of cold drawn steel wire conforming to the minimum requirements of AASHTO M 32 (ASTM A 82) and shall be welded into the finished mesh fabric in accordance with AASHTO M 55 (ASTM A 185). Galvanization shall be applied after the mesh is fabricated and conform to the minimum requirements of AASHTO M 111.
 - 4.4.4 Fasteners - Fasteners shall be high strength hexagonal cap screw bolts and nuts conforming to AASHTO M 164 (ASTM A 325). Galvanizing fastener elements, including washers, shall be in accordance with AASHTO M 232 (ASTM A 153). Bolts and nuts nominal diameter will be shown in the plans and supplied in accordance with the fasteners as specified previously.
 - 4.4.5 Steel Strap Connections - The steel strap connection bar and plate shall meet the same requirements as the reinforcing and tie strips specified above. Bolts, nuts, and washers shall conform to the requirements for the fasteners specified above. Coatings for connecting devices shall be as specified below.

- 4.4.6 Clevis Loop and Mesh Loop - Clevis loops and mesh loops shall be fabricated of cold drawn steel wire conforming to the requirements of AASHTO M 32 and welded in accordance with AASHTO M 55 and shall develop a minimum stress of 0.9 F_y.
- 4.4.7 Connector Bar - Connector bar shall be fabricated of cold drawn steel wire conforming to the requirements of AASHTO M 32.

Holes for bolts shall be punched in the location shown. Surfaces resulting from punching holes for bolts shall be galvanized in accordance with AASHTO M 111. Those parts of the connecting devices which are threaded shall be galvanized in accordance with AASHTO M 232. Alignment pins are to be hot dip galvanized.

All connecting devices shall be to the dimensions shown on the plans. Connecting members and soil reinforcement devices shall be assembled prior to galvanization. All connecting devices shall be true to size and free from defects that may impair their strength or durability.

Any damage sustained by any part of the connecting devices, bolts or reinforcing devices during any phase of fabrication, storage or erection shall be repaired to the satisfaction of the Engineer at no increase in contract cost.

- 4.5 Select Granular Backfill Material - All backfill material used in the Mechanically Stabilized Earth structure volume, as shown on the plans, shall be reasonably free (maximum of 0.1%) from organic and otherwise deleterious materials, and it shall be approved by the Engineer prior to use. The material shall conform to the following gradation limits and be tested at the established frequencies in the TDOT “Procedures for the Sampling and Testing, and Acceptance of Materials and Products (SOP 1-1)”. The Contractor shall also provide test data from an approved laboratory certifying that the material meets the following:

- 4.5.1 Gradation as determined by AASHTO T 27.

SIEVE SIZE	PERCENT PASSING
4 Inches	100
3/8 Inch	0-75
No. 4	0-25
No. 8	0-10
No. 16	0-5

Note: Size Nos. 1 through 78 as listed in order of Table 1 Standard Sizes of Processed Aggregate in Section 903.22 of Standard Specifications meet the above gradation requirements.

4.5.2 In addition, the backfill must conform to all of the following requirements:

1. Soundness - The material shall be substantially free from shale or other soft, poor durability particles. The material shall have a sodium sulfate loss of less than 12 percent after five (5) cycles determined in accordance with AASHTO T 104.
2. The Plasticity Index (P.I.), as determined by AASHTO T 90, shall not exceed 6. (Note: with the above gradation this requirement would be no longer applicable.)
3. The material shall exhibit an angle of internal friction of not less than 34 degrees as determined by the standard direct shear test AASHTO T 236 on the portion finer than the No. 4 sieve, using a sample of the material compacted to 95 percent of AASHTO T 99. No testing is required for backfills where 80 percent of sizes are greater than 3/8 inch.
4. Electrochemical requirements - The backfill shall meet the following criteria:

REQUIREMENTS	TEST METHOD
ph= 5-10	AASHTO T 289 – 91
Resistivity > 3000 ohm centimeters ¹	AASHTO T 288 – 91
Chlorides < 100 parts per million	AASHTO T 291 – 91
Sulfates < 200 parts per million	AASHTO T 290 – 91
Organic Content < 1%	AASHTO T 267 – 86

1. If the resistivity is greater or equal to 5000 ohm centimeters the chloride and sulfates requirements may be waived.

5. Unit weight- The unit weight of the backfill material (at optimum condition) shall meet the requirements of the approved shop drawings or plans.

- 4.6 Concrete Leveling Pad, Traffic Barrier and Coping - The concrete shall conform to the requirements of the Standard Specifications for Class A concrete.
- 4.7 Acceptance of Material - The contractor shall furnish the Engineer a Certificate of Compliance certifying the above materials comply with the applicable contract specifications. A copy of all test results performed by the Contractor necessary to assure contract compliance shall be furnished to the Engineer.

5.0 Construction

- 5.1 Wall Excavation - Unclassified excavation shall be in accordance with the requirements of the Standard Specifications and in reasonably close conformity with the limits and construction lines shown on the plans. Temporary excavation support as required shall be the responsibility of the Contractor.
- 5.2 Foundation Preparation - The foundation for the MSE wall shall be graded level for a minimum width equal to the width of the reinforced volume and leveling pad plus one (1) foot, or as shown on the plans, using the top of the leveling pad as the grade elevation. Prior to wall construction, the foundation shall be compacted to 95 percent of optimum density, as directed by the Engineer. Any foundation soils found to be unsuitable shall be removed as directed by the Engineer and replaced with select granular backfill material compacted to 95 percent of AASHTO T 99 methods.

At each panel foundation level, a precast reinforced or a cast-in-place unreinforced concrete leveling pad of the type shown on the plans shall be provided. The concrete shall be Class A concrete with compressive strength of 3000 psi (28 day strength). The leveling pad shall be cured a minimum of 12 hours before placement of wall panels.

- 5.3 Wall Erection - Where a proprietary wall system is used, a field representative shall be available during the erection of the wall to assist the fabricator, Contractor, and Engineer. If there is more than one wall of the same type on the project, this requirement will apply to construction of the initial wall only. After the initial wall, the representative will be available on an as-needed basis, as requested by the Engineer, during construction of the remainder of the walls. Wall erection shall be in conformance with the latest edition of the MSE wall construction manual as published by the wall supplier.

It shall be the responsibility of the Contractor to consult with the designer/supplier and to utilize the proper methods necessary to achieve a

vertical face for the final wall. Blocks should be placed in successive horizontal lifts as backfill placement proceeds per the manufacturer's recommendations.

Cast-in-place concrete shall be placed on top of wall panels to allow precast coping elements on top of the wall to be brought to proper grade.

Prior to placing any select backfill material on any soil reinforcement device, all connections to the blocks shall be completed.

- 5.4 Backfill Placement - Backfill placement shall closely follow the erection of each lift of blocks. Backfill shall be placed in such a manner as to avoid any damage or disturbance to the wall materials including blocks, soil reinforcements, and connections, or misalignment of the facing blocks or reinforcing elements. Any wall materials which may become damaged or disturbed during backfill placement, or due to wall settlement prior to completion of the project shall be either removed and replaced at the Contractor's expense or corrected, as directed by the Engineer. Any misalignment or distortion of the wall facing blocks due to placement of backfill outside the limits of this section shall be corrected, as directed by the Engineer. Backfill placement methods near the facing shall assure that no voids exist directly beneath the reinforcing elements.

Backfill shall be compacted to 95 percent of the maximum density as determined by AASHTO T 99. When the backfill supports a spread footing of a bridge or other structural load, the top 5 feet shall be compacted to 100 percent of the maximum density. For backfills containing more than 30 percent retained on the $\frac{3}{4}$ inch sieve, a method compaction consisting of a minimum of 4 passes of a heavy roller shall be used.

The moisture content of the backfill material prior to and during compaction shall be uniformly distributed throughout each layer. Backfill materials shall have a placement moisture content less than or equal to the optimum moisture content. Backfill material with a placement moisture content in excess of the optimum moisture content shall be removed and reworked until the moisture content is uniformly acceptable throughout the entire lift. The optimum moisture content shall be determined in accordance with AASHTO T 99.

At each soil reinforcement device level, backfill shall be compacted to the full length of reinforcement devices and be sloped to drain away from the wall before placing and attaching the next layer of reinforcement devices. The compacted backfill shall be level with the connecting device before the reinforcement device can be connected. Compaction within three feet

of the backface of the wall facing shall be achieved with at least three (3) passes of a light weight mechanical tamper, roller, or vibratory system.

Unless otherwise indicated on the plans or directed by the Engineer, soil reinforcement devices shall be placed at 90 degrees to the face of the wall. The maximum lift thickness before compaction shall be ten (10) inches and shall closely follow panel erection. The Contractor shall decrease this lift thickness, if required, to obtain the specified density.

At the end of each day's operation, the Contractor shall slope the last level of backfill away from the wall facing to rapidly direct runoff or rainwater away from the wall face. In addition, the contractor shall not allow surface runoff from adjacent areas to enter the wall construction site.

6.0 Method of Measurement

The method of measurement shall be square foot area of the wall face, measured from the top of footing (or bottom of wall for walls without footings) to the top of the wall excluding any appurtenances.

7.0 Basis of Payment

The mechanically stabilized earth wall, complete in place and accepted, shall be paid for at the contract square foot bid price. The bid price for walls shall include as required: all costs for grading and compaction of the wall foundation, undercutting and backfilling of weak surficial zones, footing excavation, pre-splitting, cast-in-place or precast coping, cast-in-place level up concrete for top panels, prefabricated modular blocks, reinforcement strips or mesh, tie strips or rods, fasteners, connectors, joint materials, leveling pads, footings, sheeting, shoring, select granular material in the reinforced mass, backfilling, hardware, filter cloth, reinforcement steel, and all miscellaneous material and labor required for the complete installation of the wall. If required for retaining wall protection against vehicle impact, the cost of the barrier wall and end terminals shall be included in the square foot cost of the wall.

H. Anchored Wall

Part A - Part A covers specifications for permanent ground anchor walls exclusive of the ground anchors.

1.0 Description

The work covered under this section includes the furnishing of all materials, labor, tools, equipment, and other incidental items for the designing, detailing, and construction of a permanent ground anchored wall. All other items included in the construction of the anchored wall not specifically mentioned herein shall conform to all applicable sections of the *Tennessee Department of Transportation Standard Specifications for Road and Bridge Construction*, henceforth referred to as the Standard Specifications, and the current *AASHTO Standard Specifications for Highway Bridges* with latest revisions.

2.0 Design Criteria

Unless otherwise directed the Contractor shall select the type of wall element to be used. The wall shall be designed for shear, moment, and lateral and axial capacity in accordance with procedures described in “Geotechnical Engineering Circular No. 4, Ground Anchors and Anchored Systems” (FHWA Report No. FHWA-SA-99-018, 1999). The Contractor shall be responsible for determining the length of the wall element and required section necessary to resist loadings due to earth and water forces while controlling ground movements. Structure design life and corrosion protection requirements for sheet-piles and soldier beams will be provided on the contract drawings. Soil properties, safety factors, anchor tendon corrosion protection requirements, wall finish and color requirements, and appurtenance locations are given in the contract plans or specifications.

The Contractor shall be familiar with the requirements for ground anchors described in Part B, “Ground Anchors.” The contractor shall incorporate all dimensional and location restrictions on ground anchor locations, spacing and length of anchor bond length and unbonded length that may affect the design of the wall system covered by this section.

- 2.1** The wall system shall be designed to resist maximum anticipated loadings calculated for the effects of any special loadings shown on the contract plans.
- 2.2** The wall shall be designed to ensure stability against passive failure of the embedded portion of the vertical wall elements (below the base of excavation). The minimum FS shall be 1.5, unless otherwise noted on the contract plans.
- 2.3** The axial load carrying capacity of the embedded portion of the vertical wall elements (below the base of the excavation) shall be evaluated. The minimum FS shall be 2.5 for elements terminating in soil and 2.0 for

elements terminating in rock, unless otherwise noted in the contract plans. The wall shall be designed to resist vertical loads including vertical anchor forces and the weight of the lagging and the vertical wall elements. Relying on transfer of vertical load into the soil behind the wall by friction shall not be permitted, unless approved by the Engineer.

- 2.4** Permanent facing shall be precast or cast-in-place reinforced concrete. Architectural facing treatments, if required, shall be as indicated on the contract drawings. The facing shall extend a minimum of 2.0 ft below the gutter line or, if applicable, the ground line adjacent to the wall unless otherwise indicated on the contract drawings.
- 2.5** The external stability of the wall shall be evaluated. Failure surfaces extending beyond the ends of the ground anchors and below the bottom of the wall shall be checked using slope stability calculations. The minimum FS with respect to external stability shall be 1.3 or 1.5 for critical wall systems as designated in the contract plans.
- 2.6** Wall Drainage. The wall drainage system shall operate by gravity and shall be capable of relieving water pressures on the back face of the wall under anticipated worst case water pressure conditions. When drainage systems are incorporated into the specific design, hydrostatic head on the back of the wall shall not exceed 6 inches above the elevation of the drainage collection pipe.

3.0 Submittals

- 3.1** Requirements for submittals are outlined in Chapter I, Section 4.0, Requirements for Contractor/Supplier Prepared Design and Plans. In addition, the following details for ground anchor walls shall be included:
 - 3.1.1** Detailed calculations for all load cases showing reactions at the anchor locations and wall shears and bending moments. Calculations for the lateral and axial capacity of the embedded portion of the wall and external stability shall also be provided.
 - 3.1.2** The relationship of the ground anchors to right-of-way and easement lines, existing buildings and other structures, utilities, streets, and other construction shall be indicated on the drawings. Department-provided utility locations shall also be shown
 - 3.1.3** Details, dimensions, and schedules of all reinforcing steel, including dowels and/or studs for attaching the concrete facing to the permanent ground anchor wall.

- 3.1.4** Details of the anchors and wall elements including spacing, length, and size of soldier beams and sheet-piles, and spacing, inclination, and corrosion protection requirements of anchors.
- 3.1.5** Detailed plans for proof and performance testing of anchors showing loading and measuring devices to be used and procedures to be followed.
- 3.1.6** All details for construction of drainage facilities associated with the wall.

- 3.2** Contractor Qualifications- The Contractor performing the design and construction of the work shall have a minimum of five (5) years of experience in anchored wall design and construction and shall submit evidence of successful completion of at least five (5) similar projects.

The Contractor's staff shall include at least one registered Professional Engineer licensed to perform work in the State of Tennessee. The Contractor shall assign an engineer to supervise the work with at least three (3) years of experience in the design and construction of anchored walls and a superintendent or foreman with a minimum of two (2) years experience in the supervision of anchored wall construction. The Contractor may not use consultants or manufacturer's representatives in order to meet the requirements of this section.

The Contractor shall submit the following to the Department for proof of meeting the requirements mentioned above:

- A. A list containing at least five (5) projects completed within the last five (5) years. For each project, the Contractor shall include with this submittal, at a minimum: (1) name of client contact, address, and telephone number; (2) location of the project; (3) contract value; and (4) scheduled completion date and actual completion date for the project.
- B. Resumes of the Contractor's staff shall be submitted to the Department for review as part of the Contractor's working drawing submittal. Only those individuals designated as meeting the qualifications requirements shall be used for the project. The Contractor cannot substitute for any of these individuals without written approval of the Department or Project Engineer. The Engineer shall approve or reject the Contractor's qualifications and staff. Work shall not be started on any anchored wall system nor materials ordered until the Contractor's qualifications have been approved by the Department. The Department may suspend the work if the Contractor substitutes unqualified personnel for approved personnel during the 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 work and no adjustment in contract time resulting from the suspension of work will be allowed.

4.0 Materials

The Contractor shall not deliver materials to the site until the Engineer has approved the submittals outlined in section 3.0. The Contractor shall protect the materials from the elements by appropriate means. Prestressing steel strands and bars shall be stored and handled in accordance with the manufacturer's recommendations and in such a manner that no damage to the component parts occurs. All steel components shall be stored under cover and protected against moisture.

4.1 Soldier Beam and Structural Steels

- 4.1.1** Steel Soldier Beams - Steel soldier beams shall be of the type and weight indicated on the approved working drawings. Steel soldier beams shall conform to the requirements of AASHTO M 183 (ASTM A 36) or AASHTO M 223 (ASTM A 572) unless otherwise specified.
- 4.1.2** Steel Sheet Piles - Steel sheet piles shall be of the type and weight indicated on the approved working drawings. Steel sheet piles shall conform to the requirements of AASHTO M 202 (ASTM A 328) or AASHTO M 270 (ASTM A 709) Grade 50.
- 4.1.3** Steel Plate - Steel used to fabricate steel studs and other devices shall conform to the requirements of AASHTO M 169 (ASTM A 108)
- 4.1.4** Steel Tube - Steel tube shall conform to the requirements of ASTM A 500.
- 4.1.5** Reinforcing Steel - Reinforcing steel shall conform to ASTM A 615. The minimum yield stress for No. 6 reinforcing bars and for smaller diameter bars shall be 40 ksi. The minimum yield stress for No. 7 reinforcing bars and larger diameter bars shall be 60 ksi.

4.2 Concrete

- 4.2.1** Cement - Portland cement shall be Type I or II and shall conform to AASHTO M 85.
- 4.2.2** Structural Concrete - Structural concrete shall conform to the requirements of Section 604 of the TDOT Standard Specifications. Structural concrete shall be Class A with a minimum 28-day

compressive strength of 3000 psi, unless otherwise noted on the contract drawings.

- 4.2.3** Lean-Mix Concrete Backfill - Lean-mix concrete backfill shall consist of Type I or Type II Portland cement, fine aggregate and water. Each cubic yard of lean-mix concrete backfill shall consist of a minimum of one sack (94lbs) of Portland cement.
- 4.2.4** Precast Concrete - Precast concrete elements such as panels shall be made by an approved plant in accordance with the the TDOT Procedure for the “Manufacture and Acceptance of Pre-cast Concrete Drainage Structures, Noise Wall panels, and Retaining wall panels.”

Out-of-state producers shall provide documentation of material quality before the manufacture of any pre-cast products (i.e. aggregate quality reports, cement/steel mill test reports, etc.)

Unless otherwise shown on the contract drawings, Portland cement concrete used in precast elements shall conform to Class D with a minimum 28-day compressive strength of 4000 psi

4.3 Drainage Materials

- 4.3.1** Drainage Aggregate - Drainage aggregate to be used as a drainage medium shall conform to section 903.17 of the Standard Specifications.
- 4.3.2** Preformed Permeable Geocomposite Drains – The preformed permeable geocomposite drains shall be continuous and a minimum of one (1) foot wide. The drains shall be placed in sections with a minimum overlap of one (1) foot and be spliced to assure continuous drainage.
- 4.3.3** Pipe and Perforated Pipe - Pipe and perforated pipe shall conform to section 610 of the Standard Specifications.

4.4 Lagging

- 4.4.1** Temporary Timber Lagging - Temporary timber lagging shall be construction grade rough cut and shall be a minimum of 3 inches thick. Where necessary, the Contractor shall provide certification that the timber conforms to the grade, species, and other specified requirements. If the timber is to be treated with a preservative, a certificate of compliance shall be furnished.

- 4.4.2** Permanent Timber Lagging – Permanent timber lagging shall conform to all requirements of section 4.4.1 and shall be constructed from structural stress-graded lumber.

5.0 Construction

5.1 General Considerations

- 5.1.1** Wall elements for anchored walls designed and constructed in accordance with this manual shall be either continuous interlocking sheet-piles or steel soldier beams that are either driven or placed in pre-drilled holes that are subsequently backfilled with lean mix or structural concrete.

5.2 Excavation

- 5.2.1** Excavation below a level of anchors shall be limited to 2 feet below the anchor level and shall not commence below this level until anchors at that level have been installed, load tested, locked off and accepted by the Department. Placement of timber lagging shall immediately follow excavation in the front of the wall.

5.3 Driven Sheet Pile and Soldier Beam Installation.

- 5.3.1** Driven sheet piles and soldier beams shall be driven to the specified minimum tip elevation shown on the approved working drawings. The Contractor shall select a sheet pile or soldier beam section that satisfies all design criteria. The Contractor shall select a driving method and pile driving and ancillary equipment consistent with the expected ground conditions at the site. The sheet-pile or soldier beam shall be driven to the specified minimum tip elevation or to the approved elevation based on bearing capacity without damaging the sheet pile or soldier beam. The interlocks between adjacent sheet piles shall not be damaged. Equipment shall be used to permit the impact energy to be distributed over the tops of the sheet pile or soldier beam.

5.4 Soldier Beam Installation in Pre-drilled Holes

- 5.4.1** Excavations required for soldier beam placement shall be performed to the dimensions and elevations on the approved working drawings. The methods and equipment used shall be selected by the Contractor.
- 5.4.2** The Contractor shall ensure that the sidewalls of the pre-drilled holes (i.e. shafts) do not collapse during drilling. Uncased shafts

may be used where the sides and the bottom of the shaft are stable and may be visually inspected prior to placing the soldier beam and concrete. Casing or drilling muds shall be used where the sides of the shaft require additional support.

- 5.4.3** The Contractor shall provide equipment for checking the dimensions and alignment of each shaft excavation. The dimensions and alignment shall be determined by the Contractor but shall be observed by the Inspector. The Inspector will check the alignment of the drilling equipment at the beginning of shaft construction and periodically thereafter. Final shaft depth shall be measured after final cleaning by the Contractor.
- 5.4.4** Loose material shall be removed from the bottom of the shaft. No more than 2 feet of standing water shall be left in the bottom of the shaft prior to beginning soldier beam installation.
- 5.4.5** The soldier beam shall be placed in the shaft without difficulty and aligned prior to general placement of concrete. The Contractor may place up to 2 feet of concrete at the bottom of the shaft to assist in aligning the soldier beam. The soldier beam shall be blocked or clamped in place at the ground surface, prior to placement of concrete.
- 5.4.6** For shafts constructed without casing or drilling muds, concrete (either structural or lean-mix backfill) may be placed by free-falling the concrete from the ground surface down the shaft and around the soldier beam. If casing is used, the placement of concrete shall begin prior to casing removal. Remove the casing while the concrete remains workable. For shafts constructed using slurry, concrete shall be placed using the tremie method from the bottom of the shaft. The tremie pipe shall be withdrawn slowly as the level of the concrete rises in the shaft and the level of the tremie pipe outlet shall never exceed the height of the slurry.

5.5 Wall Tolerances

- 5.5.1** Soldier beams shall be placed at the locations shown on the approved working drawings and shall not deviate by more than 1 foot along the horizontal alignment of the wall. The wall shall not deviate from the vertical alignment shown on the contract drawings by more than 4 inches in each plane.
- 5.5.2** The soldier beam or sheet pile tip shall be installed to within 1 foot of the specified tip elevation shown on the approved working drawings.

5.5.3 Whenever a soldier beam deviates in location or plumbness by more than the tolerance given in these guidelines, the Contractor, at his option, may provide corrective measures such as:
1) rebuilding soldier beams; 2) redesigning soldier beam; 3) adjust soldier beam spacing by adding additional soldier beams; 4) redesigning concrete facing; 5) building up the soldier beam section, or 6) other methods.

5.6 Welding and Splicing

5.6.1 Splicing of sheet piles or soldier beams shall not be permitted, unless approved by the Department. All structural welding of steel and steel reinforcement shall be performed by certified welders qualified to perform the type of welding shown on the shop drawings. All sheet piles or soldier beams shall be cutoff to a true plane at the elevations shown on the approved working drawings. All cutoff lengths shall remain the property of the Contractor and shall be properly disposed.

5.7 Timber Lagging Installation

5.7.1 Timber lagging shall be placed from the top-down in sufficiently small lifts immediately after excavation to prevent erosion of materials into the excavation. Prior to lagging placement, the soil face shall be smoothed to create a contact surface for the lagging. Large gaps behind the lagging shall be backfilled and compacted prior to applying any loads to the ground anchors.

5.7.2 A gap shall be maintained between each vertically adjacent lagging board for drainage between adjacent lagging sections. In no case shall lagging be placed in tight contact to adjacent lagging.

5.8 Drainage System Installation

5.8.1 The Contractor shall handle preformed permeable geocomposite drains in such a manner as to ensure the geocomposite drain is not damaged in any way. Care shall be taken during placement of the geocomposite drain not to entrap dirt or excessive dust in the geocomposite drain that could cause clogging of the drainage system. Delivery, storage, and handling of the geocomposite drains shall be as provided in the plans or based on the manufacturer's recommendations.

5.8.2 Drainage geocomposite strips shall be placed and secured tightly against the timber lagging with the fabric facing the lagging. A continuous sheet of drainage geocomposite that spans between

adjacent soldier beams shall not be allowed. Seams and overlaps between adjacent composites shall be made according to the special provisions or the manufacturer's recommendations and specifications. Repairs shall be performed at no additional cost to the Department and shall conform to the plans or the manufacturer's recommendation.

5.8.3 Where drainage aggregate is used to construct a vertical drain behind the permanent wall and in front of the lagging, the drainage aggregate shall be placed in horizontal lifts. The construction of the vertical drain should closely follow the construction of the precast facing elements. Care should be exercised to ensure that connection devices between wall elements and facing elements are not damaged during the placement of the drainage aggregate.

5.8.4 Perforated collector pipe shall be placed within the permeable material to the flow line elevations and at the location shown on the approved working drawings. Outlet pipes shall be placed at the low end of the collector pipe and at other locations shown or specified in the approved working drawings.

5.9 Concrete Facing Installation

5.9.1 For permanent cast-in-place and precast concrete facings, concrete manufacture, handling, placement, and finishing shall conform to the requirements in Section 8 "Concrete Structures" of the AASHTO "Standard Specifications for Highway Bridges." Connections used to secure the facing to wall elements shall conform to the details shown on the approved working drawings. The exposed surface of the concrete facing shall receive a Class I finish as specified in Section 8 "Concrete Structures," unless a special architectural treatment is specified.

6.0 Method of Measurement

The method of measurement shall be square foot area of the wall face, measured from the top of footing (or bottom of wall for walls without footings) to the top of the wall excluding any appurtenances.

7.0 Basis of Payment

Permanently ground anchored wall, measured as defined above, will be paid for at the contract unit price bid. Such payment will include all costs for concrete, reinforcing steel, excavation, backfill, lagging, piles, anchors, labor, design and all other materials and equipment including grouting, drilling holes, post-tensioning, performance and

evaluating all tests, submitting records of tests, all tools and other miscellaneous items necessary to complete the work

Additional area of wall required due to unforeseen foundation conditions or other reasons and approved by the Engineer will be paid for on the basis of the unit price bid. If required for retaining wall protection against vehicle impact, the cost of the barrier wall and end terminals shall be included in the square foot cost of the wall.

H. Anchored Wall, Part B – Part B covers specifications for the design, construction and testing of Permanent Ground Anchors.

1.0 Description

The work covered under this section includes the furnishing of all materials, labor, tools, equipment, and other incidental items for the designing, detailing, and construction of permanent ground anchors. All other items included in the construction of the permanent ground anchors not specifically mentioned herein shall conform to all applicable sections of the *Tennessee Department of Transportation Standard Specifications for Road and Bridge Construction*, henceforth referred to as the Standard Specifications, the current *AASHTO Standard Specifications for Highway Bridges* with latest revisions and the latest version of Post Tensioning Institute (PTI) Standards, including 1. *PTI, “Post Tensioning Manual”*, 2. *PTI “Specification for Unbonded Single Strand Tendons”*, 3. *PTI “Recommendations for Prestressed Rock and Soil Anchors.”*

Unless otherwise noted the Contractor shall select the ground anchor type, drilling method, grouting method, and grout pressures, determine the ground anchor capacity, bond length, free stressing (unbonded) length, and anchor diameter. The Contractor shall be responsible for installing ground anchors that will develop the load-carrying capacity indicated on the approved working drawings in accordance with the testing subsection of this section. The anchor tendon shall be protected from corrosion as shown on the approved working drawings and in accordance with the requirements of this specification.

2.0 Design Criteria

2.1 Unless otherwise directed the Contractor shall select the type of tendon to be used. The tendon shall be sized so the design load does not exceed 60 percent of the specified minimum tensile strength of the prestressing steel. The lock-off load for the tendon shall be chosen based on anticipated time or activity dependent load changes, but shall not exceed 70 percent of the specified minimum tensile stress of the prestressing steel. The prestressing steel shall be sized so the maximum test load does not exceed 80 percent of the specified minimum tensile strength of the prestressing steel.

- 2.2** The Contractor shall be responsible for determining the bond length necessary to develop the design load indicated on the approved working drawings. The minimum bond length shall be 15 feet for strand tendons in rock and 10 feet for bar tendons in rock. The minimum bond length shall be 15 feet for strand and bar tendons in soil. The minimum tendon bond length shall be 10 feet.
- 2.3** The free stressing length (unbonded length) for rock and soil anchors shall not be less than 10 feet for bar tendons and 15 feet for strand tendons. The free stressing length shall extend at least 5 feet or 20 percent of the height of the wall, whichever is greater, behind the critical failure surface. The critical failure surface shall be evaluated using slope stability or similar procedures.

3.0 Submittals

Requirements for submittals are outlined in Chapter I, Section 4.0, Requirements for Contractor/Supplier Prepared Design and Plans. In addition to the submittal requirements outlined in Chapter I, Section 4.0 the Contractor shall submit the following at the same time:

- 3.1** Contractor qualifications as outlined in Part A, section 3.2 of these anchored wall design and construction requirements.
- 3.2** The working drawings and design submission shall include the following:
- 3.2.1** A ground anchor schedule giving:
- A. Ground anchor number
 - B. Ground anchor design load
 - C. Type and size of tendon
 - D. Minimum total anchor length
 - E. Minimum bond length
 - F. Minimum tendon bond length
 - G. Minimum unbonded length
- 3.3** A drawing of the ground anchor tendon and the corrosion protection system including details for the following:
- A. Spacers and their location
 - B. Centralizers and their location
 - C. Unbonded length corrosion protection system
 - D. Bond length corrosion protection system
 - E. Anchorage and trumpet
 - F. Anchorage corrosion protection system

- 3.4** Certificates of Compliance for the following materials , if used. The certificate shall state that the materials or assemblies to be provided will fully comply with the requirements of the contract.
- A. Prestressing steel, strand or bar
 - B. Portland cement
 - C. Prestressing hardware
 - D. Bearing plates
 - E. Corrosion protection system
- 3.5** The Contractor shall submit to the Engineer for review and approval or rejection mill test reports for the prestressing steel and the bearing plate steel. The Engineer may require the Contractor to provide samples of any ground anchor material intended for use on the project. The prestressing steel and bearing plates shall not be incorporated in the work without the Engineer’s approval.
- 3.6** The Contractor shall submit to the Engineer for review and approval or rejection calibration data for each test jack, load cell, primary pressure gauge and reference pressure gauge to be used. Testing cannot commence until the Engineer has approved these calibrations.
- 3.7** The Contractor shall submit to the Engineer within twenty calendar days after the completion of the ground anchor work a report containing the following:
- A. Prestressing steel manufacturer’s mill test reports for the tendons incorporated in the installation
 - B. Grouting records indicating the cement type, quantity injected and the grout pressures
 - C. Ground anchor test results
 - D. As-built drawings showing the location and orientation of each ground anchor, anchor capacity, tendon type, total anchor length, bond length, unbonded length, and tendon bond length as installed and locations of all instruments installed by the Department.
- 3.8** Existing Conditions – Prior to beginning work, the Department shall provide utility location plans to the Contractor. The Contractor is responsible for contacting a utility location service to verify the location of underground utilities before starting work.

The Contractor shall survey the condition of adjoining properties and make records and photographs of any evidence of settlement or cracking of any adjacent structures. The Contractor’s report of this survey shall be delivered to the Department before work begins.

4.0 Materials

4.1 General

- 4.1.1** The Contractor shall not deliver materials to the site until the Engineer has approved the submittals outlined in Section 3.0.
- 4.1.2** The Contractor shall protect all materials from theft, vandalism, and the elements by appropriate means. Prestressing steel strands and bars shall be stored and handled in accordance with the manufacturer's recommendations and in such a manner that no damage to the component parts occurs. All steel components shall be protected from the elements at all times. Cement and additives for grout shall be stored under cover and protected against moisture.

4.2 Anchorage Devices

- 4.2.1** Stressing anchorages shall be a combination of either steel bearing plate with wedge plate and wedges, or a steel bearing plate with a threaded anchor nut. The steel bearing and wedge plate may also be combined into a single element. Anchorage devices shall be capable of developing 95 percent of the specified minimum ultimate tensile strength of the prestressing steel tendon. The anchorage devices shall conform to the static strength requirements of Section 3.1.6 (1) and Section 3.1.8 (1) and (2) of the latest edition of the PTI "*Guide Specifications for Post-Tensioning Materials.*"
- 4.2.2** The bearing plate shall be fabricated from steel conforming to AASHTO M 183 or M 222 specifications, or equivalent, or may be a ductile iron casting conforming to ASTM A 536.
- 4.2.3** The trumpet shall be fabricated from a steel pipe or tube or from PVC pipe. Steel pipe or tube shall conform to the requirements of ASTM A 53 for pipe or ASTM A 500 for tubing. Steel trumpets shall have a minimum wall thickness of 0.1 inch for diameters up to 4 inches and 0.2 inch for larger diameters. PVC pipe shall conform to ASTM A 1785, Schedule 40 minimum. PVC trumpets shall be positively sealed against the bearing plate and aligned with the tendon to prevent cracking during stressing.
- 4.2.4** Anchorage covers shall be fabricated from steel or plastic with a minimum thickness of 0.1 inch. The joint between the cover and the bearing plate shall be watertight.

4.2.5 Wedges shall be designed to preclude premature failure of the prestressing steel due to notch or pinching effects under static and dynamic strength requirements of Section 3.1.8 (1) and 3.1.8 (2) of the PTI “*Post Tensioning Manual*.” Wedges shall not be reused.

4.2.6 Wedges for epoxy coated strand shall be designed to be capable of biting through the epoxy coating and into the strand. Removal of the epoxy coating from the strand to allow the use of standard wedges shall not be permitted. Anchor nuts and other threadable hardware for epoxy coated bars shall be designed to thread over the epoxy coated bar and still comply with the requirements for carrying capacity.

4.3 Prestressing Steel

4.3.1 Ground anchor tendons shall be fabricated from single or multiple elements of one of the following prestressing steels:

- A. Steel bars conforming to AASHTO M 275
- B. Seven-wire, low relaxation strands conforming to AASHTO M 203
- C. Compact, seven-wire, low-relaxation strands conforming to ASTM A 779
- D. Epoxy coated strand conforming to ASTM A 882
- E. Epoxy coated reinforcing steel bars conforming to ASTM A 775

4.3.2 Centralizers shall be provided at maximum intervals of 10 feet with the deepest centralizer located 1 foot from the end of the anchor and the upper centralizer for the bond zone located no more than 5 feet from the top of the tendon bond length. Spacers shall be used to separate the steel strands of strand tendons. Spacers shall be provided at maximum intervals of 10 feet and may be combined with centralizers.

4.4 Prestressing Steel Couplers

Prestressing steel bar couplers shall be capable of developing 100 percent of the minimum specified ultimate tensile strength of the prestressing steel bar. Steel strands used for a soil or rock anchor shall be continuous with no splices, unless approved by the Engineer.

4.5 Centralizers

4.5.1 Centralizers shall be fabricated from plastic, steel or material, which is nondetrimental to the prestressing steel. Wood shall not

be used. The centralizer shall be able to support the tendon in the drill hole and position the tendon so a minimum of 2 inches of grout cover is provided and shall permit grout to freely flow around the tendon and up the drill hole.

- 4.5.2** Centralizers are not required on pressure injected anchors installed in coarse grained soils when the grouting pressure exceeds 145 psi nor on hollow stem-augered anchors when they are grouted through the auger with grout having a slump of 9 inches or less.

4.6 Spacers

Spacers shall be used to separate elements of a multi-element tendon and shall permit grout to freely flow around the tendon and up the drill hole. Spacers shall be fabricated from plastic, steel or material, which is non-detrimental to the prestressing steel. Wood shall not be used. A combination centralizer-spacer may be used.

4.7 Tendon Bond Length Encapsulations

When the contract plans require the tendon bond length to be encapsulated to provide additional corrosion protection, the encapsulation shall be fabricated from one of the following:

- A. High density corrugated polyethylene tubing conforming to the requirements of AASHTO M 252 and having a minimum wall thickness of 0.06 inch except pregrouted tendons, which may have a minimum wall thickness of 0.04 inch.
- B. Deformed steel tubing or pipes conforming to ASTM A 52 or A 500 with a minimum wall thickness of 0.2 inch.
- C. Corrugated, polyvinyl chloride tubes manufactured from rigid PVC compounds conforming to ASTM D 1784, Class 13464-B.
- D. Fusion-bonded epoxy conforming to the requirements of AASHTO M 284.

4.8 Heat Shrinkable Sleeves

Heat shrinkable sleeves shall be fabricated from a radiation crosslinked polyolefin tube internally coated with an adhesive sealant. Prior to shrinking, the tube shall have a nominal wall thickness of 0.025 inch. The adhesive sealant inside the heat shrinkable tube shall have a nominal thickness of 0.02 inch.

4.9 Sheath

A sheath shall be used as part of the corrosion protection system for the unbonded length portion of the tendon. The sheath shall be fabricated from one of the following:

- A. A polyethylene tube pulled or pushed over the prestressing steel. The polyethylene shall be Type II, III or IV as defined by ASTM D 1248 (or approved equal). The tubing shall have a minimum wall thickness of 0.06 inch.
- B. A hot-melt extruded polypropylene tube. The polypropylene shall be cell classification B55542-11 as defined by ASTM D 4101 (or approved equal). The tubing shall have a minimum wall thickness of 0.06 inch.
- C. A hot-melt extruded polyethylene tube. The polyethylene shall be high density Type III as defined by ASTM D 1248 (or approved equal). The tubing shall have a minimum wall thickness of 0.06 inch.
- D. Steel tubing conforming to ASTM A 500. The tubing shall have a minimum wall thickness of 0.2 inch.
- E. Steel pipe conforming to ASTM A 53. The pipe shall have a minimum wall thickness of 0.2 inch.
- F. Plastic pipe or tube of PVC conforming to ASTM D 1784 Class 13464-B. The pipe or tube shall be Schedule 40 at a minimum.
- G. A corrugated tube conforming to the requirement of the tendon bond length encapsulation (Part 4.7).

4.10 Bondbreaker

The bondbreaker shall be fabricated from a smooth plastic tube or pipe having the following properties: (1) resistant to chemical attack from aggressive environments, grout, or corrosion inhibiting compound; (2) resistant to aging by ultraviolet light; (3) fabricated from material nondetrimental to the tendon; (4) capable of withstanding abrasion, impact, and bending during handling and installation; (5) enable the tendon to elongate during testing and stressing; and (6) allow the tendon to remain unbonded after lockoff.

4.11 Cement Grout

Type I, II, III or V Portland cement conforming to AASHTO M 85 shall be used for grout. The grout shall be a pumpable neat mixture of cement and water and shall be stable (bleed less than 2 percent), fluid, and provide a minimum 28-day compressive strength of at least 3000 psi measured in accordance with ASTM C 109 at the time of stressing.

4.12 Admixtures

Admixtures which control bleed, improve flowability, reduce water content, and retard set may be used in the grout subject to the approval of the Engineer. Admixtures, if used, shall be compatible with the prestressing steels and mixed in accordance with the manufacturer's recommendation. Expansive admixtures may only be added to the grout used for filling sealed encapsulations, trumpets, and anchorage covers. Accelerators shall not be permitted.

4.13 Water

Water for mixing grout shall be potable, clean, and free of injurious quantities of substances known to be harmful to Portland cement or prestressing steel.

4.14 Corrosion Inhibiting Compound

The corrosion inhibiting compound placed in either the free length or the trumpet areas shall be an organic compound (i.e. grease or wax) with appropriate polar moisture displacing, corrosion inhibiting additives and self healing properties. The compound shall permanently stay viscous and be chemically stable and nonreactive with the prestressing steel, the sheathing material, and anchor grout.

4.15 Grout Tubes

Grout tubes shall have an adequate inside diameter to enable the grout to be pumped to the bottom of the drill hole. Grout tubes shall be strong enough to withstand a minimum grouting pressure of 145 psi. Post-grout tubes shall be strong enough to withstand post-grouting pressures.

5.0 Construction

5.1 Tendon Storage and Handling

5.1.1 Tendons shall be handled and stored in such a manner as to avoid damage or corrosion. Damage to the prestressing steel, the corrosion protection, and/or the epoxy coating as a result of abrasions, cuts, nicks, welds or weld splatter will be cause for rejection by the Engineer. The prestressing steel shall be protected if welding is to be performed in the vicinity. Grounding of welding leads to the prestressing steel is forbidden. Prestressing steel shall be protected from dirt, rust, or other deleterious substances. A light coating of rust on the steel is acceptable. If heavy corrosion or pitting is noted, the Engineer shall reject the affected tendons.

- 5.1.2** The Contractor shall use care in handling and storing the tendons at the site. Prior to inserting a tendon in the drill hole, the Contractor and the Inspector shall examine the tendon for damage to the encapsulation and the sheathing. If, in the opinion of the Inspector, the encapsulation is damaged, the Contractor shall repair the encapsulation in accordance with the tendon supplier's recommendations. If, in the opinion of the inspector, the smooth sheathing has been damaged, the Contractor shall repair it with ultra high molecular weight polyethylene tape. The tape should be spiral wound around the tendon to completely seal the damaged area. The pitch of the spiral shall ensure a double thickness at all points.
- 5.1.3** Banding for fabricated tendons shall be padded to avoid damage to the tendon corrosion protection. Upon delivery, the fabricated anchors or the prestressing steel for fabrication of the tendons on site and all hardware shall be stored and handled in such a manner to avoid mechanical damage, corrosion, and contamination with dirt or deleterious substances.
- 5.1.4** Lifting of the pre-grouted tendons shall not cause excessive bending, which can debond the prestressing steel from the surrounding grout.
- 5.1.5** Prestressing steel shall not be exposed to excessive heat (i.e. more than 446° F).

5.2 Anchor Fabrication

- 5.2.1** Anchors shall be either shop or field fabricated from material conforming to part 4 of this section and as shown in the approved working drawings and schedules.
- 5.2.2** Prestressing steel shall be cut with an abrasive saw or, with the written approval of the prestressing steel supplier, an oxyacetylene torch.
- 5.2.3** All of the tendon bond length, especially for strand, must be free of dirt, manufacturer's lubricants, corrosion-inhibitive coatings, or other deleterious substances that may significantly affect the grout-to-tendon bond or the service life of the tendon.
- 5.2.4** Pre-grouting of encapsulated tendons shall be done on an inclined, rigid frame or bed by injecting the grout from the low end of the tendon.

5.3 Drilling

- 5.3.1** Drilling methods shall be left to the discretion of the Contractor, whenever possible. The Contractor shall be responsible for using a drilling method to establish a stable hole of adequate dimensions, within the tolerances specified. Drilling methods may involve, amongst others, rotary, percussion, rotary/percussive or auger drilling; or percussive or vibratory driven casing.
- 5.3.2** Holes for anchors shall be drilled at the locations and to the length, inclination and diameter shown on the approved working drawings. The drill bit or casing crown shall not be more than 0.12 inch smaller than the specified hole diameter. At the ground surface the drill hole shall be located within 1 foot of the location shown on the approved working drawings. The drill hole shall be located so the longitudinal axis of the drill hole and the longitudinal axis of the tendon are parallel. In particular, the ground anchor hole shall not be drilled in a location that requires the tendon to be bent in order to enable the bearing plate to be connected to the supported structure. At the point of entry the ground anchor shall be installed within plus/minus three (3) degrees of the inclination from horizontal shown on the approved working drawings. At the point of entry the horizontal angle made by the ground anchor and the structure shall be within plus/minus three (3) degrees of a line drawn perpendicular to the plane of the structure unless otherwise shown on the approved working drawings. The ground anchors shall not extend beyond the right-of-way or easement limits shown on the contract drawings.

5.4 Tendon Insertion

- 5.4.1** Tendons shall be placed in accordance with the approved working drawings and details and the recommendations of the tendon manufacturer or specialist anchor contractor. The tendon shall be inserted into the drill hole to the desired depth without difficulty. When the tendon cannot be completely inserted, the Contractor shall remove the tendon from the drill hole and clean or redrill the hole to permit insertion. Partially inserted tendons shall not be driven or forced into the hole.
- 5.4.2** Each anchor tendon shall be inspected by Department field personnel during installation into the drill hole or casing. Damage to the corrosion protection system shall be repaired, or the tendon replaced if not repairable. Loose spacers or centralizers shall be reconnected to prevent shifting during insertion. Damaged fusion bonded epoxy coatings shall be repaired in accordance with the

manufacturer's recommendations. If the patch is not allowed to cure prior to inserting the tendon in the drill hole, the patched area shall be protected by tape or other suitable means.

5.4.3 The rate of placement of the tendon into the hole shall be controlled such that the sheathing, coating, and grout tubes are not damaged during installation of the tendon. Anchor tendons shall not be subjected to sharp bends. The bottom end of the tendon may be fitted with a cap or bullnose to aid its insertion into the hole, casing or sheathing.

5.5 Grouting

5.5.1 The Contractor shall use a neat cement grout or a sand-cement grout. The cement shall not contain lumps or other indications of hydration. Admixtures, if used, shall be mixed in accordance with the manufacturer's recommendation.

5.5.2 The grouting equipment shall produce a grout free of lumps and undispersed cement. A positive displacement grout pump shall be used. The pump shall be equipped with a pressure gauge to monitor pressures. The pressure gauge shall be capable of measuring pressures of at least 145 psi or twice the actual grout pressure used by the Contractor, whichever is greater. The grouting equipment shall be sized to enable the grout to be pumped in one continuous operation. The mixer should be capable of continuously agitating the grout.

5.5.3 The grout shall be injected from the lowest point of the drill hole. The grout may be pumped through grout tubes, casings, hollowstem-augers, or drill rods. The grout can be placed before or after insertion of the tendon. The quantity of the grout and the grout pressures shall be recorded. The grout pressures and grout takes shall be controlled to prevent excessive heave or fracturing.

5.5.4 After the tendon is installed, the drill hole may be filled in one continuous grouting operation except that pressure grouting shall not be used in the free length zone. The grout at the top of the drill hole shall not contact the back of the structure or the bottom of the trumpet.

5.5.5 If the ground anchor is installed in a fine-grained soil using drill holes larger than 6 inches in diameter, then the grout above the top of the bond length shall be placed after the ground anchor has been tested and stressed. The Engineer will allow the Contractor to grout the entire drill hole at the same time if the Contractor can

demonstrate that their particular ground anchor system does not derive a significant portion of its load-carrying capacity from the soil above the bond length portion of the ground anchor.

- 5.5.6** If grout protected tendons are used for ground anchors anchored in rock, then pressure grouting techniques shall be utilized. Pressure grouting requires that the drill hole be sealed and that the grout be injected until a minimum 50 psi grout pressure (measured at the top of the drill hole) can be maintained on the grout for at least five (5) minutes.
- 5.5.7** The grout tube may remain in the hole on completion of grouting if the tube is filled with grout.
- 5.5.8** After grouting, the tendon shall not be loaded for a minimum of three (3) days.

5.6 Anchorage Installation

- 5.6.1** The anchor bearing plate and the anchor head or nut shall be installed perpendicular to the tendon, within plus/minus three (3) degrees and centered on the bearing plate, without bending or kinking of the prestressing steel elements. Wedge holes and wedges shall be free of rust, grout and dirt.
- 5.6.2** The stressing tail shall be cleaned and protected from damage until final testing and lock-off. After the anchor has been accepted by the Engineer, the stress tail shall be cut to its final length according to the tendon manufacturer's recommendations.
- 5.6.3** The corrosion protection surrounding the unbonded length of the tendon shall extend up beyond the bottom seal of the trumpet or 4 inches into the trumpet if no trumpet seal is provided. If the protection does not extend beyond the seal or sufficiently far enough into the trumpet, the Contractor shall extend the corrosion protection or lengthen the trumpet.
- 5.6.4** The corrosion protection surrounding the unbonded length of the tendon shall not contact the bearing plate or the anchor head during testing and stressing. If the protection is too long, the Contractor shall trim the corrosion protection to prevent contact.

5.7 Corrosion Protection

5.7.1 Protection Requirements

Corrosion protection requirements shall be determined by the Department and shall be shown on the contract plans. The corrosion protection systems shall be designed and constructed to provide reliable ground anchors for temporary and permanent structures.

5.7.2 Anchorage Protection

5.7.2.1 All stressing anchorages permanently exposed to the atmosphere shall receive a grout-filled cover, except, for restressable anchorages where a corrosion inhibiting compound must be used. Stressing anchorages encased in concrete at least 2 inches thick do not require a cover.

5.7.2.2 The trumpet shall be sealed to the bearing plate and shall overlap the unbonded length corrosion protection by at least 4 inches. The trumpet shall be long enough to accommodate movements of the structure and the tendon during testing and stressing. On strand tendons, the trumpet shall be long enough to enable the tendon to make a transition from the diameter of the tendon along the unbonded length to the diameter of the tendon at the wedge plate without damaging the encapsulation.

5.7.2.3 The trumpet shall be completely filled with grout, except restressable anchorages must use corrosion inhibiting compounds. Compounds may be placed any time during construction. Compound filled trumpets shall have a permanent seal between the trumpet and the unbonded length corrosion protection. Grout must be placed after the ground anchor has been tested and stressed to the lock-off load. Trumpets filled with grout shall have either a temporary seal between the trumpet and the unbonded length corrosion protection or the trumpet shall fit tightly over the unbonded length corrosion protection for a minimum of 4 inches.

5.7.3 Unbonded Length Protection

5.7.3.1 Corrosion protection of the unbonded length shall be provided by a combination of sheaths, sheath filled with a corrosion inhibiting compound or grout, or a heat shrinkable tube internally coated with a mastic compound, depending on the tendon class. The corrosion inhibiting compound shall completely coat the tendon elements, fill the void between them and the sheath, and fill the

interstices between the wires of 7-wire strands. Provisions shall be made to retain the compound within the sheath.

5.7.3.2 The corrosion protective sheath surrounding the unbonded length of the tendon shall be long enough to extend into the trumpet, but shall not come into contact with the stressing anchorage during testing. Any excessive protection length shall be trimmed off.

5.7.3.3 For pregrouted encapsulations and all Class I tendons, a separate bondbreaker or common sheath shall be provided for supplemental corrosion protection or to prevent the tendon from bonding to the grout surrounding the unbonded length.

5.7.4 Unbonded Length/Bond Length Transition

The transition between the corrosion protection for the bonded and unbonded lengths shall be designed and fabricated to ensure continuous protection from corrosive attack.

5.7.5 Tendon Bond Length Protection for Grout Protected Tendons (Class II)

5.7.5.1 Cement grout can be used to protect the tendon bond length in non-aggressive ground when the installation methods ensure that the grout will remain fully around the tendon. The grout shall overlap the sheathing of the unbonded length by at least 1 inch.

5.7.5.2 Centralizers or grouting techniques shall ensure a minimum of 0.5 inch of grout cover over the tendon bond length.

5.7.6 Tendon Bond Length Protection for Encapsulated Tendons (Class I)

5.7.6.1 A grout-filled, corrugated plastic encapsulation or a groutfilled, deformed steel tube shall be used. The prestressing steel can be grouted inside the encapsulation prior to has been placed.

5.7.6.2 Centralizers or grouting techniques shall ensure a minimum of 0.5 inch of grout cover over the encapsulation.

5.7.7 Epoxy

A fusion-bonded epoxy may be used to provide a layer of protection for the steel tendon in addition to the cement grout.

5.7.8 Coupler Protection

5.7.8.1 On encapsulated bar tendons (Class I), the coupler and any adjacent exposed bar sections shall be covered with a corrosion-proof compound or wax-impregnated cloth tape. The coupler area shall be covered by a smooth plastic tube, complying with the requirements set forth in 4.9, overlapping the adjacent sheathed tendon by at least 1 inch. The two joints shall be sealed each by a coated heat shrink sleeve of at least 6 inches in length, or approved equal. The corrosion-proof compound shall completely fill the space inside the cover tube.

5.7.8.2 Corrosion protection details for strand couplers, if specifically permitted, shall be submitted for approval of the Engineer.

5.8 Stressing, Load Testing, and Acceptance

5.8.1 General

Each ground anchor shall be tested. No load greater than ten (10) percent of the design load can be applied to the ground anchor prior to testing. The maximum test load shall be no less than 1.33 times the design load and shall not exceed 80 percent of the specified minimum ultimate tensile strength of the prestressing steel of the tendon. The test load shall be simultaneously applied to the entire tendon. Stressing of single-element tendons shall not be permitted.

5.8.2 Stressing Equipment

5.8.2.1 The testing equipment shall consist of:

- A. A dial or vernier scale capable of measuring to the nearest .001 inch shall be used to measure the ground anchor movement. The movement measuring device shall have a minimum travel equal to the theoretical elastic elongation of the total anchor length at the maximum test load and it shall have adequate travel so

the ground anchor movement can be measured without resetting the device at an interim point.

- B. A hydraulic jack and pump shall be used to apply the test load. The jack and a calibrated primary pressure gauge shall be used to measure the applied load. The jack and primary pressure gauge shall be calibrated by an independent firm as a unit. The calibration shall have been performed within forty-five (45) working days of the date when the calibration submittals are provided to the Engineer. Testing cannot commence until the Engineer has approved the calibration. The primary pressure gauge shall be graduated in 100 psi increments or less. The ram travel shall be at least 6 inches and preferably not be less than the theoretical elongation of the tendon at the maximum test load. If elongations greater than 6 inches are required, restroking can be allowed.
- C. A calibrated reference pressure gauge shall also be kept at the site to periodically check the production (i.e. primary pressure) gauge. The reference gauge shall be calibrated with the test jack and primary pressure gauge. The reference pressure gauge shall be stored indoors and not subjected to rough treatment.
- D. The Contractor shall provide an electrical resistance load cell and readout to be used when performing an extended creep test.
- E. The stressing equipment shall be placed over the ground anchor tendon in such a manner that the jack, bearing plates, load cells and stressing anchorage are axially aligned with the tendon and the tendon is centered within the equipment.
- F. The stressing equipment, the sequence of stressing and the procedure to be used for each stressing operation shall be determined at the planning stage of the project. The equipment shall be used strictly in accordance with the manufacturer's operating instructions.
- G. Stressing equipment shall preferably be capable of stressing the whole tendon in one stroke to the specified test load and the equipment shall be capable of stressing the tendon to the maximum specified test load within

75 percent of the rated capacity. The pump shall be capable of applying each load increment in less than 60 seconds.

- H. The equipment shall permit the tendon to be stressed in increments so that the load in the tendon can be raised or lowered in accordance with the test specifications, and allow the anchor to be lift-off tested to confirm the lock off load.
- I. Stressing equipment shall have been calibrated, within an accuracy of plus or minus two (2) percent, a maximum of 45 days prior to use. The calibration certificate and graph shall be available on site at all times. The calibration shall be traceable to the National Institute of Standards and Technology (NIST).

5.8.3 Load Test Setup

5.8.3.1 Dial gauges shall bear on the pulling head of the jack and their stems shall be coaxial with the tendon direction. The gauges shall be supported on an independent, fixed frame, such as a tripod, which will not move as a result of stressing or other construction activities during the operation.

5.8.3.2 Prior to setting the dial gauges, the Alignment Load (AL) shall be accurately placed on the tendon. The magnitude of the AL depends on the type and length of the tendon.

5.8.3.3 Regripping of strands, which would cause overlap wedge bites, or wedge bites on the tendon below the anchor head, shall be avoided.

5.8.3.4 Stressing and testing of multiple element tendons with single element jacks is not permitted.

5.8.3.5 Stressing shall not begin until the grout has reached adequate strength.

5.8.4 Performance Tests

5.8.4.1 Five (5) percent of the ground anchors or a minimum of three (3) ground anchors, whichever is greater, shall be performance tested in accordance with the procedures described in this section. The Engineer shall select the ground anchors to be performance tested. The remaining

ground anchors shall be tested in accordance with the proof test procedures as outlined in 5.8.6.

5.8.4.2 The performance test shall be made by incrementally loading and unloading the ground anchor in accordance with the schedule provided in section 5.8.5. The load shall be raised from one increment to another immediately after recording the ground anchor movement. The ground anchor movement shall be measured and recorded to the nearest 0.001 inch with respect to an independent fixed reference point at the alignment load and at each increment of load. The load shall be monitored with the primary pressure gauge. The reference pressure gauge shall be placed in series with the primary pressure gauge during each performance test. If the load determined by the reference pressure gauge and the load determined by the primary pressure gauge differ by more than ten (10) percent, the jack, primary pressure gauge and reference pressure gauge shall be recalibrated at no expense to the Department. At load increments other than the maximum test load, the load shall be held just long enough to obtain the movement reading.

5.8.4.3 The maximum test load in a performance test shall be held for ten (10) minutes. A load cell shall be used to monitor small changes in load during constant load-hold periods.

5.8.4.4 The jack shall be adjusted as necessary in order to maintain a constant load. The load-hold period shall start as soon as the maximum test load is applied and the ground anchor movement, with respect to a fixed reference, shall be measured and recorded at 1 minute, 2,3,4,5,6 and 10 minutes. If the ground anchor movement between one (1) minute and ten (10) minutes exceeds .04 inch, the maximum test load shall be held for an additional 50 minutes. If the load hold is extended, the ground anchor movement shall be recorded at 15, 20, 30, 40, 50 and 60 minutes.

5.8.5 Steps for the Performance Test – The steps for the performance test are detailed in the table on the following page:

Step	Loading	Applied Load	Record and Plot Total Movement (d_{ti})	Record and Plot Residual Movement (d_{ri})	Calculate Elastic Movement (d_{ei})
1	Apply alightment load (AL)				
2	Cycle 1	0.25DL	d_{t1}		$d_{t1} - d_{r1} = d_{e1}$
		AL		d_r	
3	Cycle 2	0.25AL	d_2		$d_{t2} - d_{r2} = d_{e2}$
		0.50DL	d_{t2}		
		AL		d_{r2}	
4	Cycle 3	0.25DL	d_3		$d_{t3} - d_{r3} = d_{e3}$
		0.50DL	d_3		
		0.75FL	d_3		
		AL		d_{r3}	
5	Cycle 4	0.25DL	d_4		$d_{t4} - d_{r4} = d_{e4}$
		0.50DL	d_4		
		0.75DL	d_4		
		1.00DL	d_{t4}		
		AL		d_{r4}	
6	Cycle 5	0.25DL	d_5		$d_{t5} - d_{r5} = d_{e5}$
		0.50DL	d_5		
		0.75DL	d_5		
		1.00DL	d_5		
		1.2DL	d_5		
		AL		d_{r5}	
7	Cycle 6	0.25DL	d_6		
		0.50DL	d_6		
		0.75DL	d_6		
		1.00DL	d_6		
		1.2DL	d_6		
		1.33DL	d_{t6} , zero reading for creep test		
8	Hold load for 10 minutes while recording movement at specified times. If the total movement measured during the load hold exceeds the specified maximum value then the load hold should be extended to a total of 60 minutes.				
9	Cycle 6 cont=d	AL		d_{r6}	Cycle 6: $d_m - d_{r6} = d_{e6}$
Notes: AL = Alignment Load, DL = Design Load, d_i = total movement at a load other than maximum for cycle, i = number identifying a specific load cycle.					

5.8.6 Proof Tests

5.8.6.1 The proof test shall be performed by incrementally loading the ground anchor in accordance with the following schedule. The load shall be raised from one increment to another immediately after recording the ground anchor movement. The ground anchor movement shall be measured and recorded to the nearest 0.001 inch with respect to an independent fixed reference point at the alignment load and at each increment load. The load shall be monitored with the primary pressure gauge. At load increments other than the maximum test load, the load shall be held just long enough to obtain the movement reading.

Proof Test Schedule

Step	Load
1	AL
2	0.25DL
3	0.50DL
4	0.75DL
5	1.00DL
6	1.20DL
7	1.33DL
8	Reduce to lock-off load
9	AL (optional)
10	Adjust to lock-off load

5.8.6.2 The maximum test load in a proof test shall be held for (10) minutes. The jack shall be adjusted as necessary in order to maintain a constant load. The load-hold period shall start as soon as the maximum test load is applied and the ground anchor movement with respect to a fixed reference shall be measured and recorded at 1,2,3,4,5,6 and 10 minutes. If the ground anchor movement between one (1) minute and ten (10) minutes exceeds 0.04 inch, the maximum test load shall be held for an additional 50 minutes. If the load hold is extended, the ground anchor movements shall be recorded at 15,20,30,40,50 and 60 minutes.

5.8.7 Extended Creep Tests

5.8.7.1 The Department shall determine if extended creep testing is required and select those ground anchors that are to be creep tested. If creep tests are required, at least two (2) ground anchors shall be tested. The stressing equipment shall be capable of measuring and maintaining the hydraulic pressure within 50 psi.

5.8.7.2 The extended creep test shall be made by incrementally loading and unloading the ground anchor in accordance with the performance test schedule provided in 5.8.5. At the end of each loading cycle, the load shall be held constant for the observation period indicated in the creep test schedule below. The times for reading and recording the ground anchor movement during each observation period shall be 1, 2, 3, 4, 5, 6, 10, 15, 20, 25, 30, 45, 60, 75, 90, 100, 120, 150, 180, 210, 240, 270 and 300 minutes as appropriate for the load increment. Each load-hold period shall start as soon as the test load is applied. In a creep test, the primary pressure gauge and reference pressure gauge will be used to measure the applied load and the load cell will be used to monitor small changes in load during constant load-hold periods. The jack shall be adjusted as necessary in order to maintain a constant load.

5.8.7.3 The Contractor shall plot the ground anchor movement and the residual movement measured in an extended creep test. The Contractor shall also plot the creep movement for each load hold as a function of the logarithm of time.

Extended Creep Test Schedule

Load	Observation period (min)
AL	
0.25DL	10
0.50DL	30
0.75DL	30
1.00DL	45
1.20DL	60
1.33DL	300

5.8.8 Ground Anchor Acceptance Criteria

5.8.8.1 A performance-tested or proof-tested ground anchor with a 10 minute load hold shall be acceptable if the: (1) ground anchor resists the maximum test load with less than 0.04 inch of movement between 1 minute and 10 minutes; and (2) total elastic movement at the maximum test load exceeds 80 percent of the theoretical elastic elongation of the unbonded length.

5.8.8.2 A performance-tested or proof-tested ground anchor with a 60 minute load hold shall be acceptable if the: (1) ground anchor resists the maximum test load with a creep rate that does not exceed 0.08 inch in the last log cycle of time; and (2) total elastic movement at the maximum test load exceeds 80 percent of the theoretical elastic elongation of the unbonded length.

5.8.8.3 A ground anchor subjected to extended creep testing is acceptable if the: (1) ground anchor resists the maximum test load with a creep rate that does not exceed 0.08 inch in the last log cycle of time; and (2) total elastic movement at the maximum test load exceeds 80 percent of the theoretical elastic elongation of the unbonded length.

5.8.8.4 The initial lift-off reading shall be within plus or minus five (5) percent of the designated lock-off load. If this criterion is not met, then the tendon load shall be adjusted accordingly and the initial lift-off reading repeated.

5.8.9 Procedures for Anchors Failing Acceptance Criteria

5.8.9.1 Anchors that do not satisfy the minimum apparent free length criteria shall be either rejected and replaced at no additional cost to the Department or locked off at no more than 50 percent of the maximum acceptable load attained. In this event, no further acceptance criteria are applied.

5.8.9.2 Regroutable anchors which satisfy the minimum apparent free length criteria but which fail the

extended creep test at the test load may be postgrouted and subjected to an enhanced creep criterion. This enhanced criterion requires a creep movement of not more than 0.04 inch between 1 and 60 minutes at test load. Anchors which satisfy the enhanced creep criterion shall be locked off at the design lock-off load. Anchors which cannot be postgrouted or regrowable anchors that do not satisfy the enhanced creep criterion shall be either rejected or locked off at 50 % of the maximum acceptable test load attained. In this event, no further acceptance criteria are applied. The maximum acceptable test load with respect to creep shall correspond to that where acceptable creep movements are measured over the final log cycle of time.

5.8.9.3 In the event that the anchor fails, the Contractor shall modify the design and/or construction procedures. These modifications may include, but are not limited to, installing additional anchors, modifying the installation methods, reducing the anchor design load by increasing the number of anchors, increasing the anchor length, or changing the anchor type. Any modification of design or construction procedures shall be at no change in the contract price. A description of any proposed modifications must be submitted to the Engineer in writing. Proposed modifications shall not be implemented until the Contractor receives written approval from the Engineer.

5.8.10 Anchor Lock-Off

5.8.10.1 After testing has been completed, the load in the tendon shall be such that after seating losses (i.e. wedge seating), the specified lock-off load has been applied to the anchor tendon.

5.8.10.2 The magnitude of the lock-off load shall be specified in the approved working drawings, or as determined by the designer.

5.8.10.3 The wedges shall be seated at a minimum load of 50% F_{pu} . If the lock-off load is less than 50% F_{pu} , shims shall be used under the wedge plate and the

wedges seated at 50% F_{pu} . The shims shall then be removed to reduce the load in the tendon to the desired lock-off load. Bar tendons may be locked off at any load less than 70% F_{pu} .

5.8.11 Anchor Lift-Off Test

After transferring the load to the anchorage, and prior to removing the jack, a lift-off test shall be conducted to confirm the magnitude of the load in the anchor tendon. This load is determined by reapplying load to the tendon to lift off the wedge plate (or anchor nut) without unseating the wedges (or turning the anchor nut). This moment represents zero time for any long time monitoring.

6.0 Method of Measurement

The method of measurement shall be square foot area of the exposed wall face as specified in section 6.0 of part A of these design and construction requirements.

7.0 Basis of Payment

Payment for ground anchors will be included in the contract unit bid price as specified in section 7.0 of part A of these design and construction requirements. If required for retaining wall protection against vehicle impact, the cost of the barrier wall and end terminals shall be included in the square foot cost of the wall.

Soil Nail Wall

I. Soil Nail Wall

Part A – Part A covers specifications for permanent soil nail walls exclusive of the shotcrete facing and wall drainage.

1.0 Description

The work covered under this section includes the furnishing of all materials, labor, tools, equipment, and other incidental items for the designing, detailing, and construction of permanent soil nails. All other items included in the construction of the soil wall not specifically mentioned herein shall conform to all applicable sections of the *Tennessee Department of Transportation Standard Specifications for Road and Bridge Construction*, henceforth referred to as the Standard Specifications, and the current American Association of State Highway and Transportation Officials (AASHTO) *Standard Specifications for Highway Bridges* with latest revisions.

The term “Soil Nail” as used in these specifications is intended as a generic term and refers to a reinforcing bar grouted into a drilled hole installed in any type of ground. Soil nail walls are built from the top down in existing ground.

Soil nailing work shall include: excavating in accordance with the staged lifts shown in the Plans; drilling soil nail drillholes to the specified minimum length and orientation indicated on the Plans; providing, placing and grouting the encapsulated or epoxy-coated nail bar tendons into the drillholes; placing drainage elements; placing shotcrete reinforcement; applying shotcrete facing over the reinforcement; attaching bearing plates and nuts; performing nail testing; and installing instrumentation (if required). Shotcrete facing and wall drainage construction is covered by the Shotcrete Facing and Wall Drainage Specification (Part B). Cast-in-place concrete facing construction (if required) is covered by the Standard Specifications and/or cast-in-place Facing Special Provisions. Soil nail wall instrumentation (if required) is covered by the Soil Nail Wall Instrumentation Specification.

2.0 Design Criteria

The wall shall be designed using the procedures contained in the Federal Highway Association (FHWA) “Manual for Design and Construction Monitoring of Soil Nail Walls”, Report No. FHWA-SA-96-018, 069. The required load and resistance factors, partial safety factors, allowable strength factors and minimum global stability factors of safety shall be in accord with the FHWA manual, unless specified otherwise. The specifications, as presented in the FHWA manual, are as follows:

Estimated soil/rock shear strength parameters, slope and external surcharge loads, type of wall facing and facing architectural requirements, soil nail corrosion

protection requirements, known utility locations easements, and right-of-ways will be as shown on the “Retaining Wall Conceptual Drawing.” The drawing will also specify if the structure is critical or non-critical, and indicate the appropriate seismic acceleration coefficient. Structural design of any individual wall elements not covered in the FHWA manual shall be by the service load or load factor design methods in conformance with the appropriate articles of the 17th Edition of the AASHTO Standard Specifications for Highway Bridges including any interim specifications.

The Contractor shall select the method of excavation, drilling method and equipment, final drillhole diameter(s), and grouting procedures, and incorporate all dimensional and locational restrictions on nail spacing and length that may affect the design of the wall system covered by this section.

- 2.1 The wall system shall be designed to resist maximum anticipated loadings calculated for the effects of any special loadings shown on the contract plans.
- 2.2 Permanent facing shall be shotcrete or cast-in-place reinforced concrete. Architectural facing treatments, if required, shall be as indicated on the contract drawings. The facing shall extend to the ground line adjacent to the wall unless otherwise indicated on the contract drawings.
- 2.3 The external stability of the wall shall be evaluated. Failure surfaces extending beyond the ends of the nails and below the bottom of the wall shall be checked using slope stability calculations. The minimum factor of safety (FS) with respect to external stability shall be 1.3, or 1.5 for critical wall systems as designated in the contract plans.
- 2.4 Wall Drainage. The wall drainage system shall operate by gravity and shall be capable of relieving water pressures on the back face of the wall under anticipated worst case water pressure conditions. When drainage systems are incorporated into the specific design, hydrostatic head on the back of the wall shall not exceed six inches above the elevation of the drainage collection pipe.

3.0 Submittals

- 3.1 Requirements for submittals are outlined in Chapter I, Section 4.0, Requirements for Contractor/Supplier Prepared Design and Plans. In addition, the following details for soil nail walls shall be included:
 - 3.1.1 A written summary report which describes the overall soil nail wall design.

- 3.1.2** Nail wall critical design cross-section(s) geometry including soil/rock strata and location, magnitude, and direction of design slope or external surcharge loads and piezometric levels.
- 3.1.3** Design criteria, including soil/rock shear strengths (friction angle and cohesion), unit weights, and ground-grout pullout resistances and nail diameter assumptions for each soil/rock stratum.
- 3.1.4** Partial safety factors/strength factors (for Service Load Design (SLD)) or load and resistance factors (for Load and Resistance Factor Design (LRFD)).
- 3.1.5** Nail wall final design cross-section(s) geometry including soil/rock strata and location, magnitude, and direction of slope of external surcharge loads and piezometric levels with critical slip surface shown along with minimum calculated global stability soil factor of safety for SLD design or for minimum global stability soil resistance/load ratio for LRFD design and required nail lengths and strengths (nail bar sizes and grades) for each nail row.
- 3.1.6** The relationship of the soil nails to right-of-way and easement lines, existing buildings and other structures, utilities, streets, and other construction shall be indicated on the drawings. Department-provided utility locations shall also be shown.
- 3.1.7** Wall elevation view showing nail locations and elevations; vertical and horizontal nail spacing; and the location of wall drainage elements and permanent facing expansion/contraction joints (if applicable) along the wall length.
- 3.1.8** A listing of the summary of quantities on the elevation drawing of each wall, including estimated wall face areas and other pay items.
- 3.1.9** Nail wall typical sections including staged excavation lift elevations, wall and excavation face batter, nail spacing and inclination, nail bar sizes, and corrosion protection details.
- 3.1.10** A typical detail of production and test nails defining the nail length, minimum drillhole diameter, inclination, and test nail bonded and unbonded test lengths.
- 3.1.11** Details, dimensions, and schedules for all nails, reinforcing steel, wire mesh, bearing plates, headed studs, etc. and/or attachment devices for shotcrete, cast-in-place or prefabrication facings.

3.1.12 Details, dimensions, and schedules of all reinforcing steel, including dowels and/or studs for attaching the concrete facing to the soil nail wall.

3.1.13 Details for terminating walls and adjacent slope construction.

3.2 Contractor Qualifications- The contractor performing the design and construction of the work shall have a minimum of five years of experience in soil nail design and construction and shall submit evidence of successful completion of at least five similar projects. The Contractor's staff shall include at least one registered Professional Engineer licensed to perform work in the State of Tennessee. The Contractor shall assign an engineer to supervise the work with at least three years of experience in the design and construction of soil nail walls and a superintendent or foreman with a minimum of two years experience in the supervision of soil nail wall construction. The Contractor may not use consultants or manufacturer's representatives in order to meet the requirements of this section. The Contractor shall submit the following to the Department for proof of meeting the requirements mentioned above:

- A. A list containing at least five projects completed within the last five years. For each project, the Contractor shall include with this submittal, at a minimum: (1) name of client contact, address, and telephone number; (2) location of the project; (3) contract value; and (4) scheduled completion date and actual completion date for the project.
- B. Resumes of the Contractor's staff shall be submitted to the Department for review as part of the Contractor's working drawing submittal. Only those individuals designated as meeting the qualifications requirements shall be used for the project. The Contractor cannot substitute for any of these individuals without written approval of the Department or Project Engineer. The Engineer shall approve or reject the Contractor's qualifications and staff. Work shall not be started on any wall system nor shall materials be ordered until the Contractor's qualifications have been approved by the Department. The Department may suspend the work if the Contractor substitutes unqualified personnel for approved personnel during the 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 work and no adjustment in contract time resulting from the suspension of work will be allowed.

3.3 Construction Site Survey – Before bidding the Work, the Contractor shall review the available subsurface information and visit the site to assess the

site geometry, equipment access conditions, and location of existing structures and above ground facilities.

The Contractor is responsible for field location and verification of the location of all utilities shown on the Plans prior to starting the Work. Maintain uninterrupted service for those utilities designated to remain in service throughout the Work. Notify the Engineer of any utility locations different from those shown on the Plans that may require nail relocations or wall design modification. Subject to the Engineer's approval, additional cost to the Contractor because of nail relocations and/or wall design modification resulting from utility locations different from those shown on the Plans will be paid as Extra Work.

Prior to the start of any wall construction activity, the Contractor and Engineer shall jointly inspect the site to observe and document the pre-construction condition of the site including existing structures and facilities. During construction, the Contractor shall observe the conditions above the soil nail wall on a daily basis for signs of ground movement in the vicinity of the wall. Immediately notify the Engineer 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. If the Engineer determines that the movements exceed those anticipated for typical soil nail wall construction and require corrective action, the Contractor shall take corrective actions necessary to stop the movement or perform repairs. When excessive movement is caused by the Contractor's methods or operations or failure to follow the specified/approved construction sequence, as determined by the Engineer, the costs of providing corrective actions will be borne by the Contractor. When caused by differing site conditions, as determined by the Engineer, the costs of providing corrective actions will be paid as Extra Work.

4.0 Materials

The Contractor shall not deliver materials to the site until the Engineer has approved the submittals outlined in section 3.0. The Contractor shall protect the materials from the elements by appropriate means. Store cement to prevent moisture degradation and partial hydration. Do not use cement that has become caked or lumpy. Store aggregates so that segregation and inclusion of foreign materials are prevented. Do not use bottom six inches of aggregate piles that are in contact with the ground. All steel components shall be stored under cover and protected against moisture. Store steel reinforcement on supports to keep steel from contacting the ground. Damage to the nail steel as a result of abrasion, cuts, nicks, welds, and weld splatter shall be cause for rejection. Do not ground welding leads to nail bars. Protect nail steel from dirt, rust, and other deleterious substances prior to installation. Heavy corrosion or pitting of nails is cause for rejection. Light rust that has not resulted in pitting is acceptable. Place protective wrap over

anchorage end of nail bar to which bearing plate and nut will be attached to protect during handling, installation, grouting, and shotcreting.

Do not move or transport encapsulated nails until the encapsulation grout has reached sufficient strength to resist damage during handling. Handle encapsulated nails in a manner that will prevent large deflections or damage. Repair encapsulated nails that are damaged or defective in accordance with the manufacturer's recommendations or remove them from the site.

Handle and store epoxy-coated bars in a way that will prevent them from being damaged beyond what is permitted by American Society for Testing and Materials (ASTM) 3963. Repair damaged epoxy coating in accordance with ASTM A775 and the coater's recommendations using an epoxy field repair kit approved by the epoxy manufacturer. Repaired areas shall have a minimum 0.1 inch coating thickness.

- 4.1** Solid Bar Nail Tendons – AASHTO M31/ASTM A615, Grade 60 or 75, ASTM A722 for Grade 150. Deformed bar, continuous without splices or welds, new, straight, undamaged, bare or epoxy-coated or encapsulated as shown on the Plans. Threaded a minimum of six inches on the wall anchorage end to allow proper attachment of bearing plate and nut. Threading may be continuous spiral deformed ribbing provided by the bar deformations (e.g. Dywidag or Williams continuous threadbars) or may be cut into a reinforcing bar. If threads are cut into a reinforcing bar, provide the next larger bar number designation from that shown on the Plans, at no additional cost.
- 4.2** Fusion Bonded Epoxy Coating – ASTM A775. Minimum 0.1 inch thickness electrostatically applied. Bend test requirements are waived. Coating at the wall anchorage end of epoxy-coated bars may be omitted over the length provided for threading the nut against the bearing plate.
- 4.3** Encapsulation – Minimum 1 mm thick corrugated HDPE tube conforming to AASHTO M252 or corrugated PVC tube conforming to ASTM D1784, Class 13464-B. Encapsulation shall provide at least 0.2 inches of grout cover over the bar and be resistant to ultraviolet light degradation, normal handling stresses, and grouting pressures. Factory fabrication of the encapsulation is preferred. Upon the Engineer's approval, the encapsulation may be field fabricated if done in strict accordance with the manufacturer's recommendations. Per FHWA-RD-89-198, the ground is considered aggressive if any one of these indicators show critical values as detailed below:

<u>PROPERTY</u>	<u>TEST DESIGNATION</u>	<u>CRITICAL VALUES</u>
Resistivity	AASHTO T-288 ASTM G 57	Below 785 ohm-in
pH	AASHTO T-289 ASTM G 51	Below 5
Sulfate	AASHTO T-290 ASTM D516M ASTM D4327	Above 200 ppm
Chloride	AASHTO T-291 ASTM D512 ASTM D4327	Above 100 ppm

- 4.4** Centralizers – Manufactured from Schedule 40 PVC pipe or tube, steel or other material not detrimental to the nail steel (wood shall not be used); sized to allow tremie pipe insertion to the bottom of the drillhole; and sized to allow grout to flow freely up the drillhole. Centralizers shall be provided at maximum intervals of 10 feet with the deepest centralizer located two feet from the end of the nail.
- 4.5** Nail Grout – Neat cement or sand/cement mixture with a minimum 3-day compressive strength of 1,500 psi and a minimum 28-day compressive strength of 3,000 psi per AASHTO T106/ASTM C109.
- 4.6** Admixtures – AASHTO M194/ASTM C494. Admixtures that control bleed, improve flowability, reduce water content and retard setting may be used in the grout subject to review and acceptance by the Engineer. Accelerators are not permitted. Expansive admixtures may only be used in grout used for filling sealed encapsulations. Admixtures shall be compatible with the grout and mixed in accordance with the manufacturer’s recommendations.
- 4.7** Cement - Portland cement shall be Type I, II, III or IV and shall conform to AASHTO M85/ASTM C150.
- 4.8** Fine Aggregate – Shall conform to AASHTO M6/ASTM C33.
- 4.9** Grout Tubes - Grout tubes shall have an adequate inside diameter to enable the grout to be pumped to the bottom of the drill hole. Grout tubes shall be strong enough to withstand a minimum grouting pressure of 145 psi.

- 4.10** Bar Couplers – Bar couplers shall develop the full ultimate tensile strength of the bar as certified by the manufacturer.

5.0 Construction

- 5.1** Site Drainage Control – Provide positive control and discharge of all surface water that may affect construction of the soil nail retaining wall. Maintain all pipes or conduits used to control surface water during construction. Repair damage caused by surface water at no additional cost. Upon substantial completion of the wall, remove surface water control pipes or conduits from the site. Alternately, with the approval of the Engineer, pipes or conduits from the site that are left in place may be fully grouted and abandoned or left in a way that protects the structure and all adjacent facilities from migration of fines through the pipe or conduit and from potential ground loss.

Based on the geotechnical site investigation, the regional groundwater table is anticipated to be below the level of the wall excavation. Localized areas of perched water or seepage may be encountered during excavation at the interface of geologic units.

Immediately contact the Engineer if unanticipated existing subsurface drainage structures are discovered during excavation. Suspend work in these areas until remedial measures meeting the Engineer's approval are implemented. Capture surface water runoff flows and flows from existing subsurface drainage structures by means independent of the wall drainage network, and convey them to an outfall structure or storm sewer, as approved by the Engineer. Cost of remedial measures required to capture and dispose of water resulting from encountering unanticipated subsurface drainage structures will be paid for as Extra Work.

- 5.2** Excavation – Coordinate the work and the excavation so the soil nail wall is safely constructed. Perform the wall construction and excavation sequence in accordance with the Plans and approved submittals. No excavations steeper than those specified herein or shown on the Plans will be made above or below the soil nail wall without written approval of the Engineer.
- 5.2.1** Excavation and Wall Alignment Survey Control – Unless specified otherwise, the Engineer will provide survey reference and control points at or offset along the top of the wall alignment at approximate 50-foot intervals prior to starting wall excavation. The Contractor will then be responsible for providing the necessary survey and alignment control during excavation of each lift, locating and drilling each drillhole within the allowable tolerances, and for performing the wall excavation and nail

installation in a manner that will allow for the construction of shotcrete facing to the specified minimum thickness and to the line and grade indicated in the Plans. Where the as-built location of the front face of the shotcrete exceeds the allowable tolerance from the wall control line shown on the Plans, the Contractor will be responsible for determining and bearing the cost of remedial measures necessary to provide proper attachment of nail head bearing plate connections and satisfactory placement of the final facing, as called for on the Plans.

- 5.2.2** General Roadway Excavation – Complete clearing, grubbing, grading and excavation above and behind the wall before commencing wall excavation. Do not overexcavate the original ground behind the wall or at the ends of the wall, beyond the limits shown on the Plans. Do not perform general roadway excavation that will affect the soil nail wall until wall construction starts. Roadway excavation shall be coordinated with the soil nailing excavation that will affect the soil nail wall until wall construction starts. Roadway excavation shall be coordinated with the soil nailing work and shall proceed from the top down in a horizontal staged excavation lift sequence. Each lift shall be excavated no deeper than mid-height between adjacent nail rows, as illustrated on the Plans, maintaining a working bench of native material to serve as a platform for the drilling equipment. The bench shall be wide enough to provide a safe working area for the drill equipment and workers.

Perform rock blasting within 200 feet of the soil nail wall using controlled blasting techniques designed by a qualified blasting consultant or a Professional Engineer registered in the State of Tennessee. Blasting shall not damage completed soil nail work or disrupt the remaining ground to be soil nailed or shotcreted. Repair damaged areas at no additional cost.

- 5.2.3** Soil Nail Wall Structure Excavation – Structure excavation in the vicinity of the wall face will require special care and effort compared with general earthwork excavation. The excavation contractor should take this into account during bidding. Due to the close coordination required between the soil nail contractor and the excavation contractor, the excavation contractor shall perform the structure excavation for the soil nail wall under the direction of the soil nail specialty contractor. The structure excavation pay limits are shown on the plans.

Excavate to the final wall face using procedures that prevent the following: (1) overexcavation; (2) ground loss, swelling, slaking,

or loosening; (3) loss of support for completed portions of the wall; (4) loss of soil moisture at the face; and (5) ground freezing. Costs associated with additional thickness of shotcrete, concrete or other remedial measures required owing to irregularities in the cut face, excavation overbreak or inadvertent overexcavation shall be borne by the Contractor.

The exposed unsupported final excavation face cut height shall not exceed the vertical nail spacing plus the required reinforcing lap or the short-term stand-up height of the ground. Excavation to the final wall excavation line and the application of shotcrete are to be completed in the same work shift unless otherwise approved by the Engineer. Application of the shotcrete may be delayed up to 24 hours if the Contractor can show that the delay will not adversely affect excavation face stability. A polyethylene film over the face of the excavation may reduce degradation of the cut face caused by changes in moisture. Damage to existing structures or structures included in the work shall be repaired and paid by the Contractor where approval is granted for the extended face exposure period.

At the Contractor's option, nails may be drilled and installed through a temporary stabilizing berm during the excavation of each lift, as illustrated on the plans. The purpose of the stabilizing berm is to prevent or minimize instability or sloughing of the final excavation face caused by ground conditions and/or drilling action. The geometry of the stabilizing berm, is illustrated in the plans as the top of the berm extending horizontally out from the bottom front face of the overlying shotcrete a distance of one foot and cut down from that point to the base grade for that excavation lift at a slope not steeper than 1H:1V. The Contractor may use a different berm geometry than what is illustrated in the Plans, upon acceptable demonstration that the different geometry provides satisfactory performance. Following the installation of nails in that lift, excavate the temporary stabilizing berm to the final wall face excavation line and clean the final excavation face of all loose materials, mud, rebound and other foreign matter that could prevent or reduce shotcrete bond. Ensure that installed nails and corrosion protection are not damaged during excavation of the stabilizing berm. Repair or replace nails or corrosion protection damaged or disturbed during excavation of the stabilizing berm, to the Engineer's satisfaction, at no additional cost. Do not excavate the stabilizing berm until the nail grout has aged for at least 24 hours. Remove hardened nail grout protruding more than 2 inches from the final wall excavation line in a manner that does not fracture the grout at the nail head. Sledge hammer removal of the grout is not allowed. The use of hand held rock chippers is

acceptable provided that their use does not damage or disturb the remaining grout at the nail head, the nail bar or the corrosion protection. Alternative excavation and soil nail installation methods that meet these objectives may be submitted to the Engineer for review, in accordance with the submittals section.

Excavation to the next lift shall not proceed until nail installation, reinforced shotcrete placement, attachment of bearing plates and nuts and nail testing have been completed and accepted in the current lift. Nail grout and shotcrete shall have cured for at least 72 hours or attained their specified 3-day compressive strength before excavating the next underlying lift. Excavating the next lift in less than 72 hours will only be allowed if the Contractor submits compressive strength test results for tests performed by a qualified independent testing lab that verify that the nail grout and shotcrete mixes being used will provide the specified 3-day compressive strengths in the lesser time.

Notify the Engineer immediately if raveling or local instability of the final wall face excavation occurs. Unstable areas shall be temporarily stabilized by buttressing the exposed face with an earth berm or other methods. Suspend work in unstable areas until remedial measures are developed.

- 5.2.4** Wall Discontinuities – Where the Contractor’s excavation and installation methods result in a discontinuous wall along any nail row, the ends of the constructed wall section shall extend beyond the ends of the next lower excavation lift by ten feet. Slopes at these discontinuities shall be constructed to prevent sloughing or failure of the temporary slopes. If sections of the wall are to be constructed at different times, prevent sloughing or failure of the temporary slopes at the end of each wall section.
- 5.2.5** Excavation Face Protrusions, Voids or Obstructions – Remove all or portions of cobbles, boulders, rubble or other subsurface obstructions encountered at the wall final excavation face that will protrude into the design shotcrete facing. Determine method of removal of face protrusions that includes safely securing remnant pieces left behind the excavation face and the prompt backfilling of voids that result from the removal of protrusions extending behind the excavation face. Notify the Engineer of the proposed method(s) for removal of face protrusions at least 24 hours prior to the onset of the removal process. Voids, overbreak, or overexcavation beyond the plan wall excavation line resulting from the removal of face protrusions or excavation operations shall be backfilled with shotcrete or concrete, as approved by the Engineer.

Removal of face protrusions and backfilling of voids or overexcavation is considered incidental to the work. Cost due to removal of unanticipated man-made obstructions will be paid as Extra Work.

- 5.3** Nail Installation – Determine the required drillhole diameter(s), drilling method, grout composition and installation method necessary to achieve the nail pullout resistance(s) in accordance with the nail testing acceptance criteria in the Nail Testing section specified herein or on the Plans.

No drilling or installation of production nails will be permitted in any soil/rock unit until successful pre-production verification testing of nails is completed in that unit and approved by the Engineer. Install verification test nails using the same equipment, methods, nail inclination and drillhole diameter as planned for the production nails. Perform pre-production verification tests in accordance with the Verification Testing Section prior to starting wall excavation and prior to installation of production nails in the specific lift in which the designated verification test nail are located. The number and location of the verification tests will be as indicated on the Plans or specified herein. Verification test nails may be installed prior to start of wall excavation through one of the following: the existing slope face, the drill platform work bench, the stabilization berm, or into the slot cuts made for the particular lift in which the verification test nails are located. Slot cuts will be just large enough to safely accommodate the drill and test nail reaction setup. Subject to the Engineer's approval, verification test nails may also be installed at angle orientations other than perpendicular to the wall face or at different locations than specified, as long as the Contractor can demonstrate that the test will be bonded into ground that is representative of the ground at the verification test nail locations designated on the Plans or herein. Install the production soil nails before the application of the reinforced shotcrete facing. At the Contractor's request and subject to the Engineer's written approval, the shotcrete facing may be applied before drilling and nail installation. Provide a blockout through the shotcrete facing at drillhole locations using PVC pipe or other suitable material to prevent damage to the facing during drilling. As part of the required construction submittals, provide the Engineer with acceptable structural design calculations demonstrating that the facing structural capacity will not be reduced and that the bearing plates are adequate to span the nail drillhole blockout through the construction facing. If this requires larger size bearing plates and/or additional reinforcement beyond that detailed on the plans, the extra cost will be incidental.

Where necessary for stability of the excavation face, the Contractor shall have the option of placing a sealing layer (flashcoat) of unreinforced shotcrete or of drilling and grouting of nails through a temporary

stabilizing berm of native soil to protect and stabilize the face of the excavation per Section 3.2.3 Wall Structure Excavation. Cost shall be incidental to the work.

The Engineer may add, eliminate, or relocate nails to accommodate field conditions. Cost adjustments associated with these modifications shall be made in accordance with the General Provisions of the Contract. The cost of any redesign, additional material, or installation modifications resulting from actions of the Contractor shall be borne by the Contractor.

5.3.1 Drilling – The drill holes for the soil nails shall be made at the locations, orientations, and lengths shown on the plans or as directed by the Engineer. Select drilling equipment and methods suitable for the ground conditions described in the geotechnical report and shown in the boring logs. Drilling methods may involve, amongst others, rotary, percussion, rotary/percussive or auger drilling; or percussive or vibratory driven casing. Select drillhole diameters(s) required to develop the specified pullout resistance and to also provide a minimum one-inch grout cover over bare or epoxy-coated nails or minimum one-half inch grout cover over the encapsulated nails. A minimum required drillhole diameter is shown on the plans. It is the Contractor's responsibility to determine the final drillhole diameter(s) required to provide the specified pullout resistance. Use of drilling muds such as bentonite slurry to assist in drill cutting removal is not allowed but air may be used. With the Engineer's approval, the Contractor may be allowed to use water or foam flushing upon successful demonstration that the installation method still provides adequate nail pullout resistance, at the Contractor's cost. If caving ground is encountered, use cased drilling methods to support the sides of the drillholes. Where hard drilling conditions such as rock, cobbles, boulders, or obstructions are described elsewhere in the contract documents or project Geotechnical Report, percussion or other suitable drilling equipment capable of drilling and maintaining stable drillholes through such materials will be used.

Immediately suspend or modify drilling operations if ground subsidence is observed and the soil nail wall is adversely affected, or if adjacent structures are damaged from the drilling operation. Immediately stabilize the adverse conditions at no additional cost.

5.3.2 Nail Bar Installation – Provide nail bars in accordance with the schedules included in the Plans. Provide centralizers sized to position the bar within one inch of the center of the drillhole. Position centralizers as shown on the Plans so their maximum center-to-center spacing does not exceed 10 feet. Also locate

centralizers within two feet of the top and bottom of the drillhole. Securely attach centralizers to the bar so that they will not shift during handling or insertion into the drill hole and will still allow grout tremie pipe insertion to the bottom of drillhole and allow grout to flow freely up the hole.

Inspect each nail bar before installation and repair or replace damaged bars or corrosion protection. Check uncased drillholes for cleanliness prior to insertion of the soil nail bar. Insert nail bars with centralizers into the drill hole to the required length without difficulty and in a way that prevents damage to the drill hole, bar, or corrosion protection. Do not drive or force partially inserted soil nails into the hole. Remove nails that cannot be fully inserted to the design depth and clean the drill hole to allow for unobstructed installation.

When using cased or hollow stem auger drilling equipment that does not allow for the centralizers to pass through the casing or auger stem, the Contractor may delete the centralizers if the neat cement grout pumped through the casing is placed using grout pressures greater than 150 psi or if the sand-cement grout placed through the stem of the auger has a slump of nine inches or less.

5.3.3 Nail Installation Tolerances. Nails shall not extend beyond the right-of-way or easement limits shown on the Plans. Nail location and orientation tolerances are:

Nail head location, deviation from plan design location; six inches any direction.

Nail inclination, deviation from plan; \pm three degrees.

Location tolerances are applicable to only one nail and not cumulative over large wall areas. Center nail bars within one inch of the center of the drillhole.

Soil nails that do not satisfy the specified tolerances due to the Contractor's installation methods will be replaced at no additional cost. Backfill abandoned nail drill holes with tremied grout. Nails that encounter unanticipated obstructions during drilling shall be relocated, as approved by the Engineer. Cost of drilling and backfilling drillholes abandoned due to unanticipated obstructions will be paid as Extra Work.

5.4 Grouting

5.4.1 Grout Mix Design. Use a neat cement grout or a sand-cement grout. Submit the proposed nail grout mix design to the Engineer

for review and approval in accordance with the submittal section. The design mix submittal shall include compressive strength test results verifying that the proposed mix will have a minimum 3-day compressive strength of 1500 psi and a minimum 28-day compressive strength of 3000 psi.

- 5.4.2** Grout Testing. Previous test results for the proposed grout mix completed within the previous year of the start of work may be submitted for initial verification of the required compressive strengths for installation of pre-production verification test nails and initial production nails. During production, nail grout shall be tested by the Contractor in accordance with AASHTO T106/ASTM C109 at a minimum frequency of one test for every 50 cubic yards of grout placed. Provide grout cube test results to the Engineer within 24 hours of testing.
- 5.4.3** Grouting Equipment. Grout equipment shall produce a uniformly mixed grout free of lumps and undispersed cement and be capable of continuously agitating the mix. Use a positive displacement grout pump equipped with a pressure gauge that can measure at least twice but no more than three times the intended grout pressure. Size the grouting equipment to enable the entire nail to be grouted in one continuous operation. Place the grout within 60 minutes after mixing or within the time recommended by the admixture manufacturer if admixtures are used. Grout not placed in the allowed time limit will be rejected.
- 5.4.4** Grouting Methods. Grout the drillhole after installation of the nail bar. Each drillhole will be grouted within two hours of completion of drilling unless otherwise approved by the Engineer. Inject the grout at the lowest point of each drill hole through a grout tube, casing, hollow-stem auger, or drill rods. Keep the outlet end of the conduit delivering the grout below the surface of the grout as the conduit is withdrawn to prevent the creation of voids. Completely fill the drillhole in one continuous operation. Cold joints in the grout column are not allowed except at the top of the test bond length of proof tested production nails. At the Contractor's option, the grout tube may remain in the hole provided it is filled with grout. Grouting before insertion of the nail is allowed provided the nail bar is immediately inserted without difficulty through the grout to the specified length.

During casing removal for drillholes advanced by either cased or hollow-stem auger methods, maintain sufficient grout level within the casing to offset the external groundwater/soil pressure and prevent hole caving. Maintain grout head or grout pressures

sufficient to ensure that the drillhole will be completely filled with grout and to prevent unstable soil or groundwater from contaminating or diluting the grout. Record the grout pressures for soil nails installed using pressure grouting techniques. Control grout pressures to prevent excessive ground heave or fracturing.

Remove the grout and nail if grouting is suspended for more than 30 minutes or does not satisfy the requirements of this specification or the Plans, and replace with fresh grout and undamaged nail bar at no additional cost.

5.5 Nail Testing. Perform both verification and proof testing designated test nails. Perform pre-production verification tests on sacrificial test nails at locations shown on the Plans or listed herein. Perform proof tests on production nails at locations selected by the Engineer. Required nail test data shall be recorded by the Engineer. Do not perform nail testing until the nail grout and shotcrete facing have cured for at least 72 hours and attained at least their specified 3-day compressive strength. Testing in less than 72 hours will only be allowed if the Contractor submits compressive strength test results, for tests performed by a qualified independent testing lab, verifying that the nail grout and shotcrete mixes being used will provide the specified 3-day compressive strength in the lesser time.

5.5.1 Proof Test Nail Unbonded Length. Provide temporary unbonded lengths for each test nail. Isolate the test nail bar from the shotcrete facing and/or the reaction frame used during testing. Isolation of a test nail through the shotcrete facing shall not affect the location of the reinforcing steel under the bearing plate. Accepted proof test nails may be incorporated as production nails provided the temporary test unbonded length is fully grouted subsequent to testing. Subsequent to testing, submit the proposed methods for test nail isolation, for providing an unbonded test length, and for grouting the unbonded length to the Engineer for review and approval in accordance with the Submittals section. Where temporary casing of the unbonded length of test nails is provided, install the casing in a way that prevents any reaction between the casing and the grouted bond length of the nail and/or the stressing apparatus.

5.5.2 Testing Equipment. Testing equipment shall include dial gauges, dial gauge support, jack and pressure gauge, electronic load cell, and reaction frame. The load cell is required only for the creep test portion of the verification test. Provide description of test setup and jack, pressure gauge and load cell calibration curves in accordance with Submittals section.

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

Apply and measure the test load with a hydraulic jack and pressure gauge. The pressure gauge shall be graduated in 50 psi increments or less. The jack and pressure gauge shall have a pressure range not exceeding twice the anticipated maximum test pressure. Jack ram travel shall be sufficient to allow the test to be done without resetting the equipment. Monitor the nail load during verification tests with both the pressure gauge and the load cell. Use the load cell to maintain constant load hold during the creep test load hold increment of the verification test.

Measure the nail head movement with a dial gauge capable of measuring to 0.001 inch. The dial gauge shall have a travel sufficient to allow the test to be done without having to reset the gauge. Visually align the gauge to be parallel with the axis of the nail and support the gauge independently from the jack, wall or reaction frame. Use two dial gauges when the test setup requires reaction against a soil cut face.

- 5.5.3** Pre-production Verification Testing of Sacrificial Test Nails. Pre-production verification testing shall be performed prior to installation of production nails to verify the Contractor's installation methods and nail pullout resistance. Perform pre-production verification tests at the locations and elevations shown on the Plans or herein and per Nail Installation Section 5.3, unless otherwise approved by the Engineer. Perform a minimum of 2 verification tests in each different soil/rock unit and for each different drilling/grouting method proposed to be used, at each wall location. Verification test nails will be sacrificial and not incorporated as production nails. Bare bars can be used for the sacrificial verification test nails.

Develop and submit the details of the verification testing arrangement, including the method of distributing test load pressures to the excavation surface (reaction frame), test nail bar size, grouted drillhole diameter, and reaction frame dimensioning to the Engineer for approval in accordance with Submittals section.

Construct verification test nails using the same equipment, installation methods, nail inclination, and drillhole diameter as planned for the production nails. Changes in the drilling or installation method may require additional verification testing as determined by the Engineer and shall be provided at no additional cost.

Test nails shall have both bonded and temporary unbonded lengths. Prior to testing, only the bonded length of the test nail shall be grouted. The temporary unbonded length of the test nail shall be at least three feet. The bonded length of the test nail shall be determined based on the production nail bar grade and size such that the allowable bar structural load is not exceeded during testing, but shall not be less than 10 feet. The allowable bar structural load during testing shall not be greater than 90 percent of the yield strength for Grade 60 and Grade 75 bars, or 80 percent of the ultimate strength for Grade 150 bars. The Contractor shall provide larger verification test bar sizes if required to safely accommodate the 10 foot minimum test bond length and testing to two times the allowable pullout resistance requirements, at no additional cost.

The verification test bonded length L_{BV} shall not exceed the test allowable bar structural load divided by twice the allowable pullout resistance value. The following equation shall be used for determining the verification test nail maximum bonded length to be used to avoid structurally overstressing the verification test nail bar size:

$$L_{BV} = C f_Y A_S / 2 Q_d, \text{ or } 10 \text{ feet, whichever is greater.}$$

L_{BV} = Maximum Verification Test Nail Bonded Length (feet)

C = 0.9 for Grade 60 and 70 bars and 0.8 for Grade 150 bars

f_Y = Bar Yield or Ultimate Stress (lbs/in²)

(Note: f_Y = 60,000 psi for Grade 60 bars, 70,000 psi for Grade 70 bars, and 150,000 psi for Grade 150 bars)

A_S = Bar Steel Area (in²)

2 = Pullout resistance safety factor

Q_d = Allowable pullout resistance (lbs/ft, pounds per linear foot of grouted nail length, specified herein or on the Plans)

The Design Test Load (DTL) during verification testing shall be determined by the following equation:

$$DTL = \text{Design Test Load (lbs)} - L_{BV} \times Q_d$$

- L_{BV} = As-built bonded test length (ft)
 Q_d = Allowable pullout resistance (lbs/ft, pounds per linear foot of grouted nail length, specified herein or on the Plans)

The Maximum Test Load (MTL) during verification testing shall be determined by the following equation:

$$MTL = \text{Maximum Test Load (lbs)} = 2.0 \times DTL$$

Verification test nails shall be incrementally loaded to a maximum test load of 200 percent of the DTL in accordance with the following loading schedule. The soil nail movements shall be recorded at each load increment.

VERIFICATION TEST LOADING SCHEDULE

<u>LOAD</u>	<u>HOLD TIME</u>
AL (.05 DTL max.)	1 minute
0.25 DTL	10 minutes
0.50 DTL	10 minutes
0.75 DTL	10 minutes
1.00 DTL	10 minutes
1.25 DTL	10 minutes
1.50 DTL (Creep Test)	60 minutes
1.75 DTL	10 minutes
2.00 DTL (Max. Test Load)	10 minutes

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

Each load increment shall be held for at least 10 minutes. The verification test nail shall be monitored for creep at the 1.50 DTL load increment. Nail movements during the creep portion of the test shall be measured and recorded at 1, 2, 3, 5, 6, 10, 20, 30, 50, and 60 minutes. The load during the creep test shall be maintained within two percent of the intended load by use of the load cell.

- 5.5.4** Proof Testing of Production Nails. Perform proof testing on 10 percent (one in 10) of the production nails in each nail row or minimum of one per row. The locations shall be designated by the Engineer. A verification test nail successfully completed during production work shall be considered equivalent to a proof test nail and shall be accounted for in determining the number of proof tests required in that particular row.

Production proof test nails shall have both bonded and temporary unbonded lengths. Prior to testing, only the bonded length of the test nail shall be grouted. The temporary unbonded length of the test nail shall be at least three feet. The bonded length of the test nail shall be determined based on the production nail bar grade and size such that the allowable bar structural load is not exceeded during testing, but shall not be less than 10 feet. Production proof test nails shorter than 13 feet in length may be constructed with less than the minimum 10 foot bond length with the unbonded length limited to three feet. The allowable bar structural load during testing shall not be greater than 90 percent of the yield strength for Grade 60 and Grade 70 bars, or 80 percent of the ultimate strength for Grade 150 bars.

The proof test bonded length - L_{BP} - shall not exceed the test allowable bar load divided by 1.5 times the allowable pullout resistance value, or above minimum lengths, whichever is greater. The following equation shall be used for sizing the proof test nail bonded length to avoid overstressing the production nail bar size:

$L_{BP} = C f_Y A_S / 1.5 Q_d$, or above minimum lengths, whichever is greater.

L_{BP} = Maximum Proof Test Nail Bonded Length (feet)
 C = 0.9 for Grade 60 and 70 bars and 0.8 for Grade 150 bars
 f_Y = Bar Yield or Ultimate Stress (lbs/in²)
(Note: f_Y = 60,000 psi for Grade 60 bars, 70,000 psi for Grade 70 bars, and 150,000 for Grade 150 bars)
 A_S = Bar Steel Area (in²)
1.5 = Pullout resistance safety factor
 Q_d = Allowable pullout resistance (lbs/ft, pounds per linear foot of grouted nail length, specified herein or on the Plans)

The Design Test Load (DTL) during proof testing shall be determined by the following equation:

$DTL = L_{BP} \times Q_d$
 L_{BP} = As -built bonded test length (feet)
 Q_d = Allowable pullout resistance (lbs/ft, pounds per linear foot of grouted nail length, specified herein or on the Plans)

The Maximum Test Load (MTL) during verification testing shall be determined by the following equation:

$$\text{MTL} = \text{Maximum Test Load (lbs)} = 1.5 \times \text{DTL}$$

Proof tests shall be performed by incrementally loading the proof test nail to a maximum test load of 150 percent of the DTL. The nail movement at each load shall be monitored by a jack 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 tests shall be in accordance with the following loading schedule. The soil nail movements shall be recorded at each load increment.

PROOF TEST LOADING SCHEDULE

<u>LOAD</u>	<u>HOLD TIME</u>
AL (.05 DTL max.)	Until Stable
0.25 DTL	Until Stable
0.50DTL	Until Stable
0.75DTL	Until Stable
1.0 DTL	Until Stable
1.25 DTL	Until Stable
1.50 DTL (Max. Test Load)	See Below

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

All load increments shall be maintained within 5 percent of the intended load. Depending on performance, either 10 minute or 60 minute creep tests shall be performed at the maximum test load (1.50 DTL). The creep period shall start as soon as the maximum test load is applied and the nail movement shall be measured and recorded at 1, 2, 3, 5, 6, and 10 minutes. Where the nail movement between 1 minute and 10 minutes exceeds 0.04 inch, the maximum test load shall be maintained for an additional 50 minutes and movements shall be recorded at 20, 30, 50, and 60 minutes.

5.5.5 Test Nail Acceptance Criteria. A test nail shall be considered acceptable when:

1. For verification tests, a total creep movement of less than 0.08 inch per log cycle of time between the 6 and 60 minute readings is measured during creep testing and the

creep rate is linear or decreasing throughout the creep test load hold period.

2. For proof tests, a total creep movement of less than 0.04 inch is measured between the 1 and 10 minute readings or a total creep movement of less than 0.08 inch is measured between the 6 and 60 minute readings and the creep rate is linear or decreasing throughout the creep test load hold period.
3. The total measured movement at the maximum test load exceeds 80 percent of the theoretical elastic elongation of the test nail unbonded length.
4. A pullout failure does not occur at the maximum test load. Pullout failure is defined as the load at which attempts to further increase the test load simply result in continued pullout movement of the test nail. The pullout failure load shall be recorded as part of the test data.

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

5.6 Test Nail Rejection. If a test nail does not satisfy the acceptance criteria, the Contractor shall determine the cause.

5.6.1 Verification Test Nails. The Engineer will evaluate the results of each verification test. Installation methods that do not satisfy the nail testing requirements shall be rejected. The Contractor shall propose alternative methods and install replacement verification test nails. Replacement test nails shall be installed and tested at no additional cost.

5.6.2 Proof Test Nails. The Engineer may require the Contractor to replace some or all of the installed production nails between a failed proof test nail and the adjacent passing proof test nail. Alternatively, the Engineer may require the installation and testing of additional proof test nails to verify that adjacent previously installed production nails have sufficient load carrying capacity. Contractor modifications may include, but are not limited to; the installation of additional proof test nails; increasing the drillhole diameter to provide increased capacity; modifying the installation or grouting methods; reducing the production nail spacing from that shown on the Plans and installing more production nails at a reduced capacity; or installing longer production nails if sufficient right-of-way is available and the pullout capacity behind the failure surface controls the allowable nail design capacity. The nails may not be lengthened beyond the temporary construction easements or the permanent right-of-way shown on the Plans. Installation and testing of additional proof test nails or installation of additional or modified nails as a result of proof test nail failure(s) will be at no additional cost.

5.7 Nail Installation Records. Records documenting the soil nail wall construction will be maintained by the Engineer, unless specified otherwise. The Contractor shall provide the Engineer with as-built drawings showing nail locations and shotcrete facing line and grade within five days after completion of the shotcrete facing and cast-in-place (CIP) facing line and grade within five days after completion of the CIP facing.

Part B - Part B covers specifications for the design and construction of the permanent shotcrete wall facing and wall drainage.

1.0 DESCRIPTION – Shotcrete facing and wall drainage work consists of furnishing all materials and labor required for placing and securing geocomposite drainage material, connection pipes, footing drains, weepholes and horizontal drains (if required), drainage gutter, reinforcing steel and shotcrete for the permanent shotcrete facing and nail head bearing plates and nuts for the soil nail walls shown on the Plans. The Work shall include any preparatory trimming and cleaning of soil/rock surfaces and shotcrete cold joints to receive new concrete.

Shotcrete shall comply with the requirements of American Concrete Institute (ACI) 506.2 Specifications for Materials, Proportioning and Application of Shotcrete, except as otherwise specified. Shotcrete shall consist of an application of one or more layers of concrete conveyed through a hose and pneumatically projected at a high velocity against a prepared surface.

Shotcrete may be produced by either a wet-mix or dry-mix process. The wet-mix process consists of thoroughly mixing all the ingredients except accelerating admixtures, but including the mixing water, introducing the mixture into the delivery equipment and delivering it by positive displacement to the nozzle. The wet-mix shotcrete shall then be air jetted from the nozzle at high velocity onto the surface. The dry-mix process consists of shotcrete without mixing water, which is conveyed through the hose pneumatically with the mixing water introduced at the nozzle. For additional descriptive information, the Contractor's attention is directed to the American Concrete Institute ACI 506R "Guide to Shotcrete."

CIP concrete facing construction (if required) is covered by the Standard Specifications and/or CIP Facing Special Provisions. Soil nails and wall excavation are covered by the Permanent Soil Nails and Wall Excavation Specification. Soil nail wall instrumentation (if required) is covered by the Soil Nail Wall Instrumentation Specification.

Where the imperative mood is used within this Specification for conciseness, "the Contractor shall" is implied.

- 1.1** Contractor's Experience Requirements - Workers, including foremen, nozzle men, finishers and delivery equipment operators, shall be fully experienced to perform the work. All shotcrete nozzle men on this project shall have experience on at least three projects in the past three years in similar permanent shotcrete application work totaling at least 10,000 square feet of wall face area and shall demonstrate ability to satisfactorily place the shotcrete. Finishers shall have experience on at least three projects in the past three years in similar permanent shotcrete application work totaling at least 10,000 square feet of wall face area.

Initial qualification of nozzle men will be based either on previous ACI certification or satisfactory completion of preconstruction test panels. The requirement for nozzle men to shoot preconstruction qualification test panels will be waived for nozzle men who can submit documented proof they have been certified in accordance with the ACI 506.3R Guide to Certification of Shotcrete Nozzle men. The Certification shall have been done by a recognized shotcrete testing lab and/or recognized shotcreting consultant and have covered the type of shotcrete to be used (plain wet-mix, plain dry-mix or steel fiber reinforced). All nozzle men will be required to periodically shoot production test panels during the course of the Work at the frequency specified herein.

Notify the Engineer not less than two days prior to the shooting of preconstruction test panels to be used to qualify nozzle men without previous ACI certification. Use the same shotcrete mix and equipment to make qualification test panels as those to be used for the soil nail wall shotcrete facing. Initial qualification of the nozzle men will be based on a visual inspection of the shotcrete density and void structure and on

achieving the specified 3-day and 28-day compressive strength requirements determined from test specimens extracted from the preconstruction test panels. Preconstruction and production test panels, core extraction and compressive strength testing shall be conducted in accordance with ACI506.2 and AASHTO T24/ASTM C42, unless otherwise specified herein. Nozzlemen without ACI Certification will be allowed to begin production shooting based on satisfactory completion of the preconstruction test panels and passing 3-day strength test requirements. Continued qualification will be subject to passing the 28-day strength tests and shooting satisfactory during production test panels.

- 1.2 Construction Submittals.** At least 15 calendar days before the planned start of shotcrete placement, submit five copies of the following information to the Engineer for review:
- a. Written documentation listing at least five permanent structural shotcrete walls successfully completed within the past three years, including photographs of the project as well as names, addresses, and phone numbers of the owner's representative.
 - b. Written documentation of the finisher's and nozzlemen's qualifications including proof of ACI certification (if applicable).
 - c. Proposed methods of shotcrete placement and of controlling and maintaining facing alignment and location and shotcrete thickness.
 - d. Shotcrete mix design including:
 - Type of Portland cement.
 - Aggregate source and gradation.
 - Proportions of mix by weight and water-cement ratio.
 - Proposed admixtures, manufacturer, dosage, and technical literature.
 - Previous strength test results for the proposed shotcrete mix completed within one year of the start of shotcreting may be submitted for initial verification of the required compressive strengths at start of production work.
 - e. Certificates of Compliance, manufacturers' engineering data and installation instructions for the drainage geotextile, geocomposite drain strip, drain grate and accessories.
 - f. Certificates of Compliance for bearing plates, nuts, drainage aggregate and PVC drain piping.

The Engineer will approve or reject the Contractor's Submittals within 10 calendar days after receipt of complete submission. The Contractor will not be allowed to begin wall construction or incorporate materials into the work until the submittal requirements are satisfied and found acceptable to the Engineer. Changes or deviations from the approved submittals must be re-submitted for approval. No adjustments in contract time will be allowed due to incomplete submittals.

Upon delivery to the project site, provide Certified mill test results for all reinforcing steel specifying the minimum ultimate strength, yield strength, elongation and chemical composition.

2.0 MATERIALS.

All materials for shotcrete shall conform to the following requirements:

Cement	AASHTO M85/ ASTM C150, Type I, II, III, or V
Fine Aggregate	AASHTO M6/ASTM C33 clean, natural
Coarse Aggregate	AASHTO M80, Class B for quality
Water	Clean and Potable. AASHTO M157/ASTM C94
Chemical Admixtures	
Accelerator	Fluid type, applied at nozzle, meeting requirements of AASHTO M194/ASTM C494/ASTM C1141
Air-Entraining Agent	AASHTO M154/ASTM C260
Water-reducer and Superplasticizer	AASHTO M195/ASTM C494 Type A,C,D,E,F, or G
Retarders	AASHTO M194/ ASTM C494 Type B or D
Mineral Admixtures	
Fly Ash	AASHTO M295/ASTM C618 Type F or C, cement replacement up to 35 percent by weight of cement
Silica Fume	ASTM C1240, 90 percent minimum silicon dioxide solids content, not to exceed 12 percent by weight of cement
Welded wire Fabric	AASHTO M55/ASTM A185 or A497

Reinforcing Bars for Shotcrete Facing	AASHTO M31/ASTM A615, Grade 60, deformed
Bearing Plates	AASHTO M183/ASTM A36
Nuts	AASHTO M291, grade B, hexagonal, fitted with beveled washer or spherical seat to provide uniform bearing
Curing Compounds	AASHTO M148, Type 1D or Type 2
Prepackaged Shotcrete	ASTM C928
Drainage	
Geotextile For: Wall Footing Drain	AASHTO M288 Class 2, Permittivity min. 0.2 per second; AOS 0.01 inch max
For Drain Strip	AASHTO M288 Class 3, Permittivity min. 0.2 per second; AOS 0.01 inch max
Drainage Aggregate	AASHTO M43/ASTM C33 No. 67 with no more than two percent passing the No. 200 sieve
Geocomposite Drain Strip	Miradrain 6000, Amerdrain 500 or approved equal
Film Protection	Polyethylene films per AASHTO M-171
PVC Connector and Drain Pipes:	
Pipe	ASTM 1785 Schedule 40 PVC, solid and perforated wall, cell classification 12545-B or 12354-C, wall thickness SDR 35, with solvent weld or elastomeric gasket joints
Fittings	ASTM D3034, cell classification 12454-B or 12454-C, wall thickness SDR35, with solvent weld or elastomeric gasket joints
Solvent Cement	ASTM D2564
Primer	ASTM F656

Materials shall be delivered, stored and handled to prevent contamination, segregation, corrosion or damage. Store liquid admixtures to prevent evaporation and freezing.

Drainage geotextile and geocomposite drain strips shall be provided in rolls wrapped in a protective covering and stored in a manner that protects the fabric from mud, dirt, dust, debris, and shotcrete rebound. Protective wrapping shall not be removed until immediately before the geotextile or drain strip is installed. Extended exposure to ultra-violet light shall be avoided. Each roll or geotextile or drain strip in the shipment shall be labeled to identify the production run.

2.1 Shotcrete Mix Design – The Contractor must receive notification from the Engineer that the proposed mix design and method of placement are acceptable before shotcrete placement can begin.

2.1.1 Aggregate – Aggregate for shotcrete shall meet the strength and durability requirements of AASHTO M6/M80 and the following gradation requirements:

<u>Sieve Size</u>	<u>Percent Passing by Weight</u>
1/2 inch	100
3/8 inch	90-100
No. 4	70-85
No. 8	50-70
No. 16	35-55
No. 30	20-35
No. 50	8-20
No. 100	2-10

2.1.2 Proportioning and Use of Admixtures – Proportion the shotcrete to be pumpable with the concrete pump furnished for the work, with a cementing materials content of at least 660 lbs per cubic yard and water/cement ratio not greater than 0.45. Do not use admixtures unless approved by the Engineer. Thoroughly mix admixtures into the shotcrete at the rate specified by the manufacturer. Accelerators (if used) shall be compatible with the cement used, non-corrosive to steel and not promote other detrimental effects such as cracking or excessive shrinkage. The maximum allowable chloride ion content of all ingredients shall not exceed 0.10% when tested to AASHTO T260.

2.1.3 Air Entrainment – Air entrainment is required for wet-mix shotcrete. The air content measured at the truck shall be between 7 to 10 percent when tested in accordance with AASHTO T152/ASTM C231. Air entrainment is not required in dry-mix shotcrete.

2.1.4 Strength and Durability Requirements - Provide a shotcrete mix capable of attaining 2000 psi compressive strength in three days

and 4000 psi in 28 days. The average compressive strength of each set of three test cores extracted from test panels or wall face must equal or exceed 85 percent of the specified compressive strength, with no individual core less than 75 percent of the specified compressive strength, in accordance with ACI 506.2. The boiled absorption of shotcrete, when tested in accordance with ASTM C642 at seven days, shall not exceed 8.0 percent.

- 2.1.5** Mixing and Batching – Aggregate and cement may be batched by weight or by volume in accordance with the requirements of ASTM C94 or AASHTO M241/ASTM C685. Mixing equipment shall thoroughly blend the materials in sufficient quality to maintain placing continuity. Ready mix shotcrete shall comply with AASTO M157. Shotcrete shall be batched, delivered, and placed within 90 minutes of mixing. The use of retarding admixtures may extend application time beyond 90 minutes if approved by the Engineer.

Premixed and packaged shotcrete mix may be provided for on-site mixing. The packages shall contain materials conforming to the Materials section of the specifications. Placing a time limit after mixing shall be per the manufacturers' recommendations.

- 2.2** Field Quality Control - Both preconstruction test panels (for nozzle men without previous ACI certification) and production test panels or test cores from the wall facing are required. Shotcreting and coring of test panels shall be performed by qualified personnel in the presence of the Engineer. The Contractor shall provide equipment, materials, and personnel as necessary to obtain shotcrete cores for testing, including construction of test panel boxes, field curing requirements and coring. Compressive strength testing will be performed by the Engineer. Shotcrete final acceptance will be based on the 28-day strength.

Shotcrete production work may commence upon initial approval of the design mix and nozzle men and continue if the specified strengths are obtained. The shotcrete work by a crew will be suspended if the test results for their work does not satisfy the strength requirements. The Contractor shall change all or some of the following: the mix, the crew, the equipment, and/or the procedures. Before resuming work, the crew must shoot additional test panels and demonstrate that the shotcrete in the panels satisfies the specified strength requirements. The cost of all work required to obtain satisfactory strength tests will be borne by the Contractor.

- 2.2.1** Preconstruction Test Panels - Each nozzle man without previous ACI certification shall furnish at least two preconstruction test

panels for each proposed mixture being considered and for each shooting position to be encountered on the job. Preconstruction test panels shall be made prior to the commencement of production work using the same equipment, materials, mixture proportions and procedures proposed for the job.

Make preconstruction test panels with minimum dimensions of 30 x 30 inches square and at least four inches thick. Slope the sides of preconstruction and production test panels at 45 degrees over the full panel thickness of release rebound. One preconstruction test panel shall include the maximum anticipated reinforcing congestion shown on the Plans. Cores extracted from the test panel shall demonstrate encapsulation of the reinforcement in accordance with ACI 506.2 equal to core grade 2 or better. The other preconstruction test panel shall be constructed without reinforcement and have cores extracted for absorption and compressive strength testing.

2.2.2 Production Test Panels - Furnish at least one production test panel or, in lieu of production test panels, nine three-inch diameter cores taken from the shotcrete facing during the first production application of shotcrete and henceforth for every 5000 ft² of shotcrete placed. Construct the production test panels simultaneously with the shotcrete facing installation at times designated by the Engineer. Make production test panels with minimum full thickness dimensions of 18 x 18 inches square and at least four inches thick.

2.2.3 Test Panel Curing, Test Specimen Extraction and Testing - Immediately after shooting, field moist cure the test panels by covering and tightly wrapping with a sheet of material meeting the requirements of ASTM C171 until they are delivered to the testing lab or test specimens are extracted. Do not immerse the test panels in water. Do not further disturb test panels for the first 24 hours after shooting. Provide at least three three-inch diameter core samples cut from each preconstruction test panel with reinforcement for core grading. Provide at least nine three-inch diameter core samples cut from each unreinforced preconstruction and production test panel for absorption and compressive strength testing. The Contractor has the option of extracting test specimens from test panels in the field or transporting to another location for extraction. Keep panels in their forms when transported. Do not take cores from the outer six inches of test panels, measured in from the top outside edges of the panel form. Trim the ends of the compressive strength cores to provide test cylinders at least three inches long. Do not trim the ends of the cores to be tested for

boiled absorption. If the Contractor chooses to take cores from the wall face in lieu of making production test panels, locations will be designated by the Engineer. Clearly mark the cores and container to identify the core locations and whether they are for preconstruction or production testing. If for production testing, mark the section of the wall represented by the cores on the cores and container. Immediately wrap cores in wet burlap or material meeting the requirements of ASTM C171 and seal in a plastic bag. Deliver cores to the Engineer or testing lab, as directed by the Engineer, within 48 hours of shooting the panels. The remainder of the panels will become the property of the Contractor. Compressive strength and boiled absorption testing will be performed by the Engineer. Upon delivery to the testing lab, samples will be placed in the moist room until the time of the test. When the test length of a core is less than twice the diameter, the correction factors given in AASHTO T24/ASTM C42 will be applied to obtain the compressive strength of individual cores. Three cores will be tested at three days and three cores will be tested at 28 days for compressive strength per AASHTO T24/ASTM C42. Three cores will be tested seven days for boiled absorption per ASTM C642.

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

3.0 Construction Requirements

- 3.1** Wall Drainage Network – Install and secure all elements of the wall drainage network as shown on the Plans or as required by the Engineer to suit the site conditions. The drainage network shall consist of installing geocomposite drain strips, PVC connection pipes and wall footing drains as shown on the Plans or as directed by the Engineer. Exclusive of the wall footing drains, all elements of the drainage network shall be installed prior to shotcreting.

Unanticipated subsurface drainage features exposed in the excavation cut face shall be captured independently of the wall drainage network and shall be mitigated prior to shotcrete application in accordance with Section 5.1 of the Soil Nail and Wall Excavation Specification (Part A). Costs due to the required mitigation will be paid for as Extra Work.

- 3.1.1** Geocomposite Drain Strips - Install geocomposite drain strips centered between the columns of nails as shown on the Plans. The drain strips shall be at least one foot wide and placed with the geotextile side against the ground. Secure the strips to the

excavation face and prevent shotcrete from contaminating the ground side of the geotextile. Drain strips are to be continuous. Splices shall be made with a one foot minimum overlap such that the flow of water is not impeded. Repair damage to the geocomposite drain strip, which may interrupt the flow of water. At the designer's option, horizontal geocomposite drain strips may be included behind horizontal shotcrete construction joints and/or where zones of localized groundwater seepage is encountered during construction.

3.1.2 Footing Drains - Install footing drains at the bottom of each wall as shown on the Plans. The drainage geotextile shall envelope the footing drain aggregate and pipe and conform to the dimensions of the trench. Overlap the drainage geotextile on top of the drainage aggregate as shown on the Plans. Replace or repair damaged or defective drainage geotextile.

3.1.3 Connection Pipes and Weepholes - Install connection pipes as shown on the Plans. Connection pipes are lengths of solid PVC pipe installed to direct water from the geocomposite drain strips into a footing drain or to the exposed face of the wall. Connect the connection pipes to the drain strips using either prefabricated drain grates as shown on the Plans or using the alternate connection method described below. Install the drain grate per the manufacturer's recommendations. The joint between the drain grate and the drain strip and the discharge end of the connector pipe shall be sealed to prevent shotcrete intrusion. Connection pipes that end at the footing drain shall be extended to the edge of the drain. Do not puncture the drainage fabric around the footing drain.

The alternative acceptable method for connection of the connector pipe to the drain strip involves cutting a hole slightly larger than the diameter of the pipe into the strip plastic core but not through the geotextile. Wrap both ends of the connection pipe in geotextile in a manner that prevents migration of fines through the pipe. Tape or seal the inlet end of the pipe where it penetrates the drain strip and the discharge end of the connector pipe in a manner that prevents penetration of shotcrete into the drain strip or pipe. To assure passage of groundwater from the drain strip into the connector pipe, slot the inlet end of the connector pipe at every 45 degrees around the perimeter of the pipe to a depth of 0.02 foot.

Weepholes, if required, shall be provided through the shotcrete facing to drain water from behind the facing. Install as shown on the Plans. Use PVC pipe to form the weephole through the

shotcrete. Cover the end of the pipe in contact with the soil with a drainage geotextile. Prevent shotcrete intrusion into the discharge end of the pipe.

3.2 Permanent Shotcrete Facing

- 3.2.1 Shotcrete Alignment and Thickness Control** - Ensure that the thickness of shotcrete satisfies the minimum requirements shown on the Plans using shooting wires, thickness control pins, or other devices acceptable to the Engineer. Install thickness control devices normal to the surface such that they protrude the required shotcrete thickness outside the surface and maintain a planar surface. The maximum distance between the wires on any surface shall be equal to the vertical nail spacing. Ensure that the alignment wires are tight, true to line, and placed to allow further tightening. Remove shooting wires after completion of shotcreting and/or screeding. Ensure that the front face of the shotcrete does not extend beyond the limits shown on the Plans.
- 3.2.2 Surface Preparation** - Clean the face of the excavation and other surfaces to be shotcreted of loose materials, mud, rebound, overspray or other foreign matter that could prevent or reduce shotcrete bond. Protect adjacent surfaces from overspray during shooting. Avoid loosening, cracking, or shattering the ground during excavation and cleaning. Remove any surface material which is so loosened or damaged, to a sufficient depth to provide a base that is suitable to receive the shotcrete. Remove material that loosens as the shotcrete is applied. Cost of additional shotcrete is incidental to the work. Divert water flow and remove standing water so that shotcrete placement will not be detrimentally affected by standing water. Do not place shotcrete on frozen surfaces.
- 3.2.3 Delivery and Application** - Maintain at all times a clean, dry, oil-free supply of compressed air sufficient for maintaining adequate nozzle velocity and for simultaneous operation of a blow pipe for cleaning away rebound. The equipment shall be capable of delivering the premixed material accurately, uniformly, and continuously through the delivery hose. Control shotcrete application thickness, nozzle technique, air pressure, and rate of shotcrete placement to prevent sagging or sloughing of freshly-applied shotcrete.

Apply shotcrete from the lower part of the area upwards to prevent accumulation of rebound. Orient nozzle approximately perpendicular to and at a distance from the working face so that rebound will be minimal and compaction will be maximized. Pay

special attention to encapsulating reinforcement. Care shall be taken while encasing reinforcing steel and mesh to keep the front face of the reinforcement clean during shooting operations so that shotcrete builds up from behind, to encase the reinforcement, and to prevent voids and sand pockets from forming. Use a blow pipe to remove rebound and overspray immediately ahead of the nozzle. Do not work rebound back into the construction. Remove rebound that does not fall clear of the working area. Hardened rebound and hardened overspray shall be removed prior to application of additional shotcrete using abrasive blast cleaning, chipping hammers, high pressure water blasting and/or other suitable techniques. When the thickness of a individual shotcrete layer is 0.5 foot or greater, or when shotcreting is conducted through two curtains of reinforcement, place shotcrete by the bench gunning method. The bench gunning method shall consist of building up a thick layer of shotcrete from the bottom of the lift and maintaining the top surface at approximately a 45-degree slope. Where shotcrete is used to complete the top ungrouted zone of the nail drill hole near the face, position the nozzle into the mouth of the drillhole to completely fill the void.

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

When using multiple layer shotcrete construction, the surface of the receiving layer shall be prepared before application of a subsequent layer by brooming the stiffening layer with a stiff bristle broom to remove all loose material, rebound, overspray or glaze prior to the shotcrete attaining initial set. If the shotcrete has set, surface preparation shall be delayed at least 24 hours, at which time the surface shall be prepared by sandblasting or high pressure water blasting to remove all loose material, rebound, hardened overspray, glaze or other material that may prevent adequate bond.

- 3.2.4** Defective Shotcrete - The Engineer shall have authority to accept or reject the shotcrete work. Shotcrete that does not conform to the

project specifications may be rejected either during the shotcrete application process, or on the basis of tests on the test panels or completed work. Repair shotcrete surface defects as soon as possible after placement. Remove and replace shotcrete that exhibits segregation, honeycombing, lamination, voids, or sand pockets. In-place shotcrete determined not to meet the specified strength requirement will be subject to remediation as determined by the Engineer. Possible remediation options include placement of additional shotcrete thickness or removal and replacement, at the Contractor's cost.

- 3.2.5** Construction Joints - Taper construction joints uniformly toward the excavation face over a minimum distance equal to the thickness of the shotcrete layer. Square joints are not permitted. The surface of the joints shall be rough, clean and sound. Provide a minimum reinforcement overlap at reinforcement splice joints as shown on the Plans. Clean and wet the surface of a joint before adjacent shotcrete is applied. Where shotcrete is used to complete the top ungrouted zone of the nail drill hole near the face, to the maximum extent practical clean and dampen the upper grout surface to receive shotcrete, similar to that of a construction joint.
- 3.2.6** Final Face Finish – Shotcrete finish shall be either an undisturbed gun finish as applied from the nozzle, or a rod, broom, wood float, rubber float, steel trowel or rough screeded finish as shown on the Plans or specified herein.
- 3.2.7** Attachment of Nail Head Bearing Plate and Nut – Attach a bearing plate and nut to each nail head as shown on the Plans. While the shotcrete is still plastic and before its initial set, uniformly seat the plate on the shotcrete by hand wrench tightening the nut. Where uniform contact between the plate and the shotcrete cannot be provided, set the plate in a bed of grout. After grout has set for 24 hours, hand wrench tighten the nut. Embed the bearing plate and nut in the wall as shown on the Plans. Ensure full shotcrete encapsulation of the bearing plate and nut that is free of any voids or pockets behind the plate. Ensure that bearing plates with headed studs are located within the tolerances shown on the Plans or specified herein.
- 3.2.8** Weather Limitations – Protect the shotcrete if it must be placed when the ambient temperature is below 40°F and falling or when it is likely to be subjected to freezing temperatures before gaining sufficient strength. Maintain cold weather protection until the in-place compressive strength of the shotcrete is greater than 724 psi. Cold weather protection includes blankets, heating under tents, or

other means acceptable to the Engineer. The temperature of the shotcrete mix, when deposited, shall not be less than 50°F or more than 95°F. Maintain the air in contact with shotcrete surfaces at temperatures above 32°F for a minimum of 7 days.

If the prevailing ambient conditions (relative humidity, wind speed, air temperature and direct exposure to sunlight) are such that the shotcrete develops plastic shrinkage and/or early drying shrinkage cracking, shotcrete application shall be suspended. The Contractor shall: reschedule the work to a time when more favorable ambient conditions prevail and/or adopt corrective measures, such as installation of sun-screens, wind breaks or fogging devices to protect the work. Remove and replace newly placed shotcrete exposed to rain that washes out cement or otherwise makes the shotcrete unacceptable.

3.2.9 Curing – Protect permanent shotcrete from loss of moisture for at least seven days after placement. Cure shotcrete by methods that will keep the shotcrete surfaces adequately wet and protected during the specified curing period. Commence curing within one hour of shotcrete application. When the ambient temperature exceeds 80°F, plan the Work so that curing can commence immediately after finishing. Complete curing in accordance with the following requirements:

3.2.9.1 Water Curing – Regulate the rate of water application to keep the surface continuously wet and to provide complete surface coverage with a minimum of runoff. The use of intermittent wetting procedures which allow the shotcrete to undergo wetting and drying during the curing period is prohibited.

3.2.9.2 Membrane Curing - Do not use curing compounds on any surfaces against which additional shotcrete or other cementitious finishing materials are to be bonded, unless the surface is thoroughly sandblasted in a manner acceptable to the Engineer. Membrane curing compounds are to be spray applied as quickly as practical after initial shotcrete set at a coverage of not less than 100 ft²/gallon.

3.2.9.3 Film Curing – Film curing with polyethylene sheeting may be used to supplement water curing on shotcrete that will be covered later with additional shotcrete or concrete. Spray the shotcrete surface with water immediately prior to installation of the polyethylene sheeting. Polyethylene sheeting shall completely cover the surfaces. Overlap the

sheeting edges for proper sealing and anchorage. Joints between sheets shall be sealed. Promptly repair any tears, holes, and other damage. Anchor sheeting as necessary to prevent billowing.

3.2.10 Permanent Shotcrete Facing Tolerances – Construction tolerances for the permanent shotcrete facing are as follows:

Horizontal location of wire mesh, rebar, headed studs on bearing plates, from Plan location: ± 0.4 inch

Headed studs location on bearing plate, from plan location: 0.2 inch

Spacing between reinforcing bars, from plan dimension: 1.0 inch

Reinforcing lap, from specified dimension: -1.0 inch

Complete thickness of shotcrete, from plan dimension:

If troweled or screed: -0.6 inch

If left as shot: -1.2 inch

Planarity of finish face surface-gap under 10 foot straightedge-any direction:

If troweled or screed: 0.6 inch

If left as shot: 1.2 inch

Nail head bearing plate, deviation from parallel to wall face: 10 degrees

3.3 Backfilling Behind Wall Facing Upper Cantilever – Compact backfill within three feet behind the wall facing upper cantilever using light mechanical tampers.

3.4 Safety Requirements – Nozzlemen and helpers shall be equipped with gloves, eye protection, and adequate protective clothing during the application of shotcrete. The Contractor is responsible for meeting all federal, state and local safety code requirements.

6.0 Soil Nail Wall Method of Measurement.

The Soil Nail Wall will be measured in square feet of the shotcrete area completed and accepted in the final work. 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 quantities will be the design quantity increased or decreased by any changes authorized by the Engineer.

7.0 Soil Nail Wall Basis of Payment.

The accepted quantity measured as provided above will be paid for at the contract unit price per square foot. Payment will be full compensation for furnishing all equipment, materials, labor, tools and incidentals necessary to complete the work as specified and as detailed on the Plans, including the work required to provide the proper shotcrete facing alignment and thickness control. All wall drainage materials including geocomposite drain strips, connection pipes, drain gates, drain aggregate and geotextile, fittings, and accessories are considered incidental to the shotcrete facing and will not be paid separately. No measurement or payment will be made for additional shotcrete or CIP concrete needed to fill voids created by irregularities in the cut face, excavation overbreak or inadvertent excavation beyond the plan final wall face excavation line, or failure to construct the facing to the specified line and grade and tolerances. The final pay quantity shall include all structural shotcrete, admixtures, reinforcement, welded wire mesh, wire holding devices, wall drainage materials, bearing plates and nuts, test panels and all sampling, testing and reporting required by the Plans and Specifications. Payment will be full compensation for all labor, equipment, materials, material tests, field tests, and incidentals necessary to acceptably fabricate and construct the production soil nails, proof test nails, and verification nails. If required for retaining wall protection against vehicle impact, the cost of the barrier wall and end terminals shall be included in the square foot cost of the wall.

Excavation for Soil Nail Wall to be included in the unit price will be the excavation volume within the zone measured from top to bottom of shotcrete wall facing and extending out six feet horizontally in front of the plan wall final excavation line. Additional excavation beyond the plan wall final excavation line resulting from irregularities in the cut face, excavation overbreak, or inadvertent excavation will not be measured. General roadway excavation above and beyond the limits described above will not be a separate wall pay item but will be measured and paid as part of the general roadway excavation including haul pay item.

Payment will be made for the following bid item included in the bid form:

<u>Pay Item</u>	<u>Measurement Unit</u>
Retaining Wall (Soil Nail Wall)	Square Foot

Chapter IV

Approved Systems

The following wall systems/suppliers have been approved for use on TDOT projects. All approved systems are also found in QPL 38 Retaining Wall Systems:

SECTION A BIN/CRIB/PRECAST GRAVITY WALLS

Doublewal Corporation

7 West Main Street
Plainville, CT 06062
Telephone: (860) 793-0295
Fax: (860) 793-2119
Website: www.doublewal.com

Evergreen Wall

Permatile Concrete Products
P.O. Box 2049
100 Beacon Road
Bristol, VA/TN 24203
Telephone: 1 (800) 662-5332
Fax: 1 (276) 669-2120
Website: www.permatile.com

PRECAST CONCRETE GRAVITY WALL

Redi-Rock Retaining Wall (Unreinforced only)
Redi-Rock International
05481 US 31 South
Charlevoix, MI 49720
Telephone: (866) 222-8400
Fax : (231) 237-9521
Website: www.redi-rock.com or www.redi-rocktn.com for Tennessee contact info

SECTION B GABION WALLS

MANUFACTURER

MACCAFERRI-USA

10303 Governor Lane Boulevard
Williamsport, MD 21795-3116
Telephone: (301)223-6910
Fax: (301)223-6134
Website: www.macaferri-northamerica.com

TERRA AQUA

1415 North 32nd Street
Fort Smith, AR 72904
Telephone: (800) 736-9089
Fax: (775) 828-1394
Website: www.terraaqua.com

SECTION C MECHANICALLY STABILIZED EARTH WALL (SEGMENTAL, PRECAST FACING)

MANUFACTURER

REINFORCED EARTH WALL

Retained Earth Wall (Formerly by Foster Geotechnical)
Reinforced Earth Company
25 Technology Parkway South, Suite 100
Norcross, GA 30092
Telephone: (770) 242-9415
Fax: (770) 242-9758
Website www.reinforcedearth.com

ARES SEGMENTAL PRECAST RETAINING WALL SYSTEM

Tensor Earth Technologies, Inc.
5883 Glenridge Drive
Suite 200
Atlanta, GA 30328
Telephone (404) 250-1290
Fax (404) 250-0461
Website www.tensarcorp.com

SSL MSE PLUS™ RETAINING WALL SYSTEM

SSL, LLC
4740 Scotts Valley Drive, Suite E
Scotts Valley, CA 95066
Telephone: (831) 430-9300
Fax: (831) 430-9340
Website www.mseplus.com

TRICON RETAINED SOIL WALL SYSTEM

TRICON Precast, LTD
15055 Henry Road
Houston, Texas 77060
Telephone: (281) 931-9832
Fax: (281) 931-0061
Website: www.triconprecast.com

SINEWALL

SineWall, LLC
7162 Liberty Centre Drive, Suite 105
West Chester, Ohio 45069
Contact: Tim Brereton
Phone: 513 759-2345
Fax: 513 297-7930
Email: brereton@sinewall.com, Web site: www.sinewall.com

Note: SineWall is currently conditionally approved for use on TDOT projects for retaining walls where an MSE Segmental Facing is an acceptable wall type and the wall(s) for the project are less than 25 feet in height (measured from top of wall to front of wall finished ground line) and the total estimated wall surface area for all MSE wall(s) for the project totals less than 10,000 square feet.

**SECTION D MECHANICALLY STABILIZED EARTH WALL
(MODULAR BLOCK FACING)**

MANUFACTURER

MESA Wall System
Tensar Earth Technologies, Inc.
5883 Glenridge Drive
Suite 200
Atlanta, GA 30328
Telephone (404) 250-1290
Fax (404) 250-0461
Website: www.tensarcorp.com

KEYSYSTEM I

Contech Construction Products
9025 Centre Pointe Drive, Suite 400
Westchester, OH 45069
Telephone: 1(800) 338-1122
Website: www.contech-cpi.com

KEYSYSTEM II Retaining Wall

Keystone Retaining Wall Systems, LLC
4444 West 78th Street
Minneapolis, Mn. 55435
Telephone: 1(800) 747-8971
Website: www.keystonewalls.com
Southeast Regional Information:
Scott Vollmer, P.E.
Regional Manager
Keystone Retaining Wall Systems LLC
7312 Still Pond Court | Raleigh, NC 27613
Office: 919-783-5422 Mobile: 919-349-1388 Fax: 866-462-4913
svollmer@keystonewalls.com
www.keystonewalls.com

LANDMARK REINFORCED WALL SYSTEM

Anchor Wall Systems
5959 Baker Road, Suite 390
Minnetonka, Minnesota 55345-5996
Telephone: (952) 933-8855
Website: www.anchorwall.com

VERSA-LOK RETAINING WALL SYSTEM

Kiltie Corporation
6348 Highway 36 Blvd., Suite 1
Oakdale, MN 55128
Telephone: (651) 770-3166
Local Contact – Chris Lazarides – (865) 363-5052
Website: www.versa-lok.com

ALLAN BLOCK AB COMMERCIAL WALL

Red River Concrete Products
4235 Guthrie Highway
P.O. Box 30399
Clarksville, Tn. 37040
Contact: Mike Brewer
Phone: 931 647-3308
Fax: 931 553-0534

Email: mbrewer@redriverproducts.com

Website: www.allanblock.com

Note: Allan Block AB Commercial Wall is currently conditionally approved for use on TDOT projects for retaining walls where an MSE Modular Block Facing is an acceptable wall type and the wall(s) for the project are less than 25 feet in height (measured from top of wall to front of wall finished ground line) and the total estimated wall surface area for all MSE wall(s) for the project totals less than 10,000 square feet.

SECTION E ANCHOR WALLS

APPROVED DESIGNERS/CONTRACTORS

BERKLE & COMPANY CONTRACTORS, INC.
ATLANTA REGIONAL OFFICE
7300 MARKS LANE
AUSTELL, GA 30168
TELEPHONE: (770) 941-5100
FAX: (770) 941-6300

COASTAL DRILLING EAST, LLC
70 GUM SPRINGS ROAD
MORGANTOWN, WV 26508
TELEPHONE: (304) 296-1120
FAX: (304) 296-1569

F & W CONSTRUCTION
1225 JOHNSON FERRY ROAD, SUITE 230
MARIETTA, GA 30068
TELEPHONE: (770) 973-9091
FAX: (770) 973-9015

GOETTLE
12071 HAMILTON AVE.
CINCINNATI, OH 45231
TELEPHONE: (513) 825-8100
FAX: (513) 825-8107

HAYWARD-BAKER, INC.
P.O. BOX 6
HERMITAGE, TN 37076
TELEPHONE: (615) 883-6445

FAX: (615) 883-6418

**THE JUDY COMPANY
8334 RUBY AVENUE
KANSAS CITY, KS 66111
TELEPHONE: (913) 422-5088
FAX: (913) 422-5307**

**NICHOLSON CONSTRUCTION COMPANY
P.O. BOX 7
2117 IMMEL MINE ROAD
MASCOT, TN 37806
TELEPHONE: (865) 933-3111
FAX: (865) 933-1652**

**SCHNABEL FOUNDATION COMPANY
1654 LOWER ROSWELL ROAD
MARIETTA, GA 30068
TELEPHONE: (770) 971-6455
FAX: (770) 977-8530**

**MORETRENCH
100 STICKLE AVE.
ROCKAWAY, NJ 07866-3146
TELEPHONE: (973) 627-2100
FAX: (973) 586-7265**

APPENDIX A

REFERENCES

1. American Association of State Highway and Transportation Officials (AASHTO), "Standard Specifications for Highway Bridges," Sixteenth Edition, 1996.
2. Elias, V., and B.R. Christopher, "Mechanically Stabilized Earth Walls and Reinforced Soil Slopes, Design and Construction Guidelines," Federal Highway Administration, FHWA-SA-96-071, 1996.
3. Federal Highway Administration, "Geotechnical Engineering Notebook, Geotechnical Guideline No. 2, Earth Retaining Structures - Review and Acceptance Procedures," June 1988.
4. Federal Highway Administration, "Standard Specifications for Construction of Roads and Bridges on Federal Highway Projects, FP-96," 1996.
5. Georgia Department of Transportation, "Standard Specifications Construction of Roads and Bridges," 1993.
6. GeoSyntec Consultants, "Geotechnical Engineering Circular No. 2, Earth Retaining Systems," Federal Highway Administration, FHWA-SA-96-038. February 1997.
7. Golder Associates, Inc., "Manual for Design and Construction Monitoring of Soil Nailed Walls," Federal Highway Administration, FHWA-SA-96-069, 1996.
8. Tennessee Department of Transportation, "Special Provision Regarding Mechanically Stabilized Earth Walls, No. 623," November 1994 (Rev. 10/29/97).
9. Tennessee Department of Transportation, "Standard Specifications for Road and Bridge Construction," March 1995.
10. Tennessee Department of Transportation, "Structures Memorandum - 034, Earth Retaining Structures," 1992.
11. Vermont Agency of Transportation, "Policy on Earth Retaining Structures," November 1995.
12. Weatherby, D.E., "Design Manual for Permanent Ground Anchor Walls," Federal Highway Administration, FHWA-RD-97-130, September 1998.

APPENDIX D- Format for Submission of a Request to Change Wall Types

Note: See Section 4.8 of Chapter 1 for criteria for consideration of a request to change a wall type, wall system and/or associated construction for a particular wall on a particular project.

The request to change a wall type, wall system and/or associated construction must be made in writing by the Contractor and submitted to the Engineer for proper processing. The request must provide all of the following information and the Engineer may request additional information deemed necessary.

- Contract No
- Project No.
- Wall No(s).
- Sheet No(s). associated with request including Retaining Wall Conceptual Sheet and any pertinent Plan, Profile, ROW, cross-section sheets.
- Detailed description of basis for request.
- Detailed tabulation of quantities and costs associated with the proposed change that clearly demonstrates that the proposed change does not increase the cost associated with construction of the wall or other aspect of the project.