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* Indicates 11 x 17 sheet; all others are 8 ½ x 11

CHAPTER 18

INTRODUCTION

It is the intent of this chapter to establish the guidelines, practices and specific requirements of the Structures and Bridge Division for the design and detailing of retaining wall structures. Specific wall types include Mechanically Stabilized Earth (MSE) walls; other wall types are under development.

Reference to AASHTO LRFD Specifications in this chapter refer to the current AASHTO LRFD Bridge Design Specifications, including interims, and VDOT Modifications (current IIM-S&B-80).

The practices and requirements set forth herein are intended to supplement or clarify the requirements of the AASHTO LRFD specifications, and to provide additional information to assist the designer. In the event of conflict(s) between the practices and requirements set forth herein and those contained in the AASHTO LRFD specifications, the more stringent requirements shall govern.

For walls used in conjunction bridge abutments, the requirements of this chapter shall be coordinated with the requirements of Chapter 17.

NOTE:

Due to the various restrictions on placing files in this manual onto the Internet, portions of the drawings shown do not necessarily reflect the correct line weights, line types, fonts, arrowheads, etc. Wherever discrepancies occur, the written text shall take precedence over any of the drawn views.

GENERAL INFORMATION

EARTH RETAINING SYSTEM CLASSIFICATION

Earth Retaining Walls (ERW) are used to retain earth materials while maintaining a grade change between the front and rear of the wall. ERWs transmit loads to the base and to possible internal reinforcement to maintain stability. Typically, ERWs are more expensive when compared to embankments; therefore, the need for an ERW should be carefully considered in preliminary design. An effort should be made to keep the retained soil height to a minimum. ERWs are used to support cut and fill slopes where space is not available for construction of flatter, more stable slopes.

For highway applications, wall systems are used for grade separations, bridge abutments, slope stabilization, and excavation support (Figure 1). Many of the available wall systems are capable of providing adequate lateral support for some or all of the applications shown in Figure 1. Most systems, however, are designed to work best and prove to be most economical or efficient for only a limited range of earth retaining system applications. Therefore, it is useful to classify common wall systems based on the factors that will govern their selection and use.

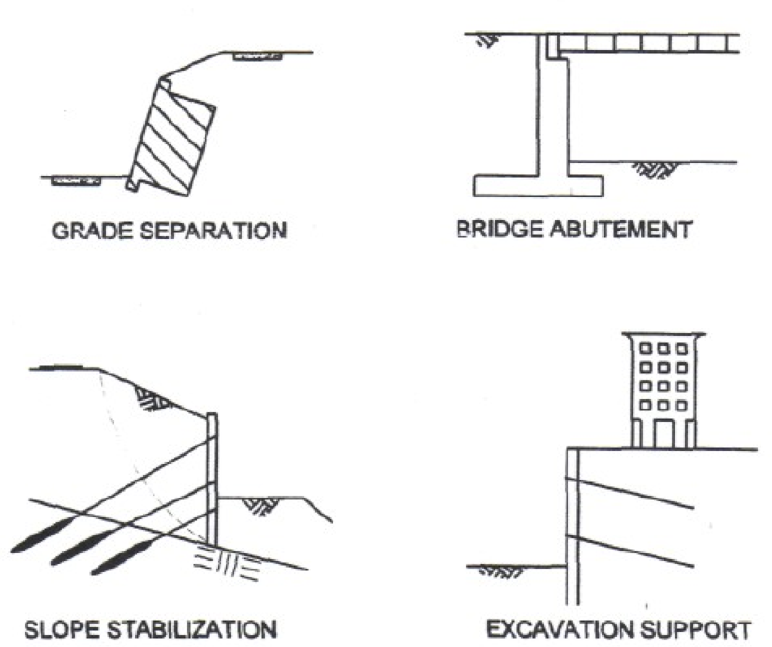


Figure 1. Applications of earth retaining systems

There are four criteria for classifying an ERW:

- Load support mechanism (externally or internally stabilized walls)
- Construction concept (cut or fill)
- System rigidity (rigid or flexible)
- Service life (temporary or permanent)

LOAD SUPPORT MECHANISM

The load support mechanism classification is based on whether the ERW is stabilized externally or internally. Externally stabilized ERWs use an external structure against which the stabilizing forces are mobilized. Internally stabilized ERWs use reinforcement that is installed within the soil mass and extend beyond a potential failure surface to mobilize the stabilizing forces. A hybrid ERW may use both external and internal support mechanisms to achieve stability.

CONSTRUCTION CONCEPT

ERWs are also classified based on the construction method used. The construction methods consist of fill or cut. Fill construction refers to an ERW that is constructed from the base to the top of the ERW (i.e. bottom-up construction). Conversely, cut construction refers to an ERW that is constructed from the top to the base of the ERW (i.e. top-down construction).

SYSTEM RIGIDITY

The rigidity of the ERW is fundamental to understanding tie development of earth pressure that develops behind and acts on the ERW. A rigid ERW moves as a unit (i.e. rigid body rotation and/or translation) and does not experience bending deformations. A flexible ERW undergoes not only rigid body rotation and/or translation, but also experiences bending deformations. In flexible ERWs, the deformations allow for the redistribution of lateral (earth) pressures from more flexible parts of the wall to the more rigid portion of the wall. Most gravity type retaining walls would be considered an example of a rigid wall. Almost all of the remaining ERW systems would be considered flexible.

A classification system for earth retaining systems is presented in File No. 18.01-3. ERWs are classified according to construction method (i.e., fill construction or cut construction) and basic mechanisms of lateral load support (i.e., externally stabilized or internally stabilized). It is important to recognize that the “cut” and “fill” designations refer to how the wall is constructed, not necessarily the nature of the earthwork (i.e., cut or fill) associated with the project. For example, a fill wall, such as a prefabricated modular gravity wall, may be used to retain earth for a major highway cut. Using the classification system in File No. 18.01-3, each wall system is given a two-part classification. For example, a sheet-pile wall is classified as an “externally stabilized cut wall system” whereas a mechanically stabilized earth (MSE) wall is classified as an “internally stabilized fill wall system”.

FILL WALL CONSTRUCTION	
Externally Stabilized	Internally Stabilized
Rigid Gravity and Semi-Gravity Walls ● Cast-in-place (CIP) concrete gravity wall ● CIP concrete cantilever / counterfort wall Prefabricated Modulus Gravity Walls ● Crib wall ● Bin wall ● Gabion wall	Mechanically Stabilized Earth (MSE) Walls ● Segmental, precast facing MSE wall ● Prefabricated modulus block facing MSE wall ●Geotextile / Geogrid / Welded Wire facing MSE wall Reinforced Soil Slopes (RSS)

CUT WALL CONSTRUCTION	
Externally Stabilized	Internally Stabilized
Non-gravity Cantilevered Walls ● Sheet-pile wall ● Soldier pile and lagging wall ● Slurry (diaphragm) wall ● Tangent / sectant pile wall ● Soil mixed wall (SMW) Anchored Walls ● Ground anchor (tieback) ● Deadman anchor	In-situ Reinforced Walls ● Soil nail wall ● Micropile wall

The selection summary charts for fill walls and cut walls are presented in Tables 1 and 2, respectively. Key selection factors, such as cost effective height range, required right-of-way, advantages and disadvantages of each wall type are also presented.

Table 1. System Selection Chart for Fill Walls.

Wall Type	Perm.	Temp.	Cost Effective Height Range (feet)	Required ROW[(1)]
Concrete gravity wall	√		3 – 10	0.5 – 0.7 H[(2)]
Concrete cantilever wall	√		6 – 28	0.4 – 0.7 H[(2)]
Concrete counterforted wall	√		26 – 40	0.4 – 0.7 H[(2)]
Concrete crib wall			6 – 20	0.5 – 0.7 H
Gabion wall[(3)]	√		6 – 20	0.5 – 0.7 H
MSE wall (precast facing)	√		10 – 60	0.7 – 1.0 H
MSE wall (modulus block facing)	√		6 – 30	0.7 – 1.0 H
MSE wall (geotextile/geogrid/welded wire facing)	√	√	6 – 45	0.7 – 1.0 H
Reinforced Soil Slopes (RSS)	√	√	10 – 45	0.5 – 1.0 H

Notes:

(1) 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.
(2) ROW requirement given is the typical wall base width as a fraction of wall height, H.
(3) Gabion walls shall not be used along freeways, principal arterial and urban roadways.

Table 1. System Selection Chart for Fill Walls (Cont'd).

Wall Type	Advantages	Disadvantages
Concrete gravity wall	Durable Requires smaller quantity of select backfill as compare to MSE walls Concrete can meet aesthetic requirements	Deep foundation support may be necessary Relatively long construction time
Concrete cantilever wall	Durable Requires smaller quantity of select backfill as compare to MSE walls Concrete can meet aesthetic requirements	Deep foundation support may be necessary Relatively long construction time
Concrete counterforted wall	Durable Requires smaller quantity of select backfill as compare to MSE walls Concrete can meet aesthetic requirements	Deep foundation support may be necessary Relatively long construction time
Concrete crib wall	Does not require skill labor or specialized equipment Rapid construction	Difficult to make height adjustments in field
Gabion wall	Does not require skill labor or specialized equipment	Need adequate source of stone Construction of wall requires significant labor
MSE wall (precast facing)	Does not require skill labor or specialized equipment Flexibility in choice of facing	Requires use of select backfill Subject to corrosion in aggressive environment (metallic reinforcement)
MSE wall (modulus block facing) (modulus block facing)	Does not require skill labor or specialized equipment Flexibility in choice of facing Blocks are easily handled	Requires use of select backfill Subject to corrosion in aggressive environment (metallic reinforcement) Positive reinforcement connection to block is difficult to achieve
MSE wall (geotextile/geogrid/ welded wire facing)	Does not require skill labor or specialized equipment Flexibility in choice of facing	Facing may not be aesthetically pleasing Geosynthetic reinforcement is subject to degradation in some environments
Reinforced Soil Slopes (RSS)	Does not require skill labor or specialized equipment Flexibility in choice of facing Vegetation provides ultraviolet light protection to geosynthetic reinforcement	Facing may not be aesthetically pleasing Geosynthetic reinforcement is subject to degradation in some environments Vegetated soil face requires significant maintenance

Table 2. System Selection Chart for Cut Walls.

Wall Type	Perm.	Temp.	Cost Effective Height Range (feet)	Required ROW[3]	Lateral Movement	Water Tightness
Sheet-pile wall	√	√	Up to 15	None	Large	Fair
Solider pile/lagging wall	√	√	Up to 25	None	Medium	Poor
Slurry (diaphragm) wall	√	√	20 – 60[1]	None[4]	Small	Good
Tangent pile wall		√	10 – 30 20 – 60[1]	None[4]	Small	Fair
Secant pile wall	√	√	10 – 25 20 – 60[1]	None[4]	Small	Fair
Anchored wall	√	√	15 – 40[2]	0.6H + anchor bond length	Small - medium	N/A
Soil nailed wall	√	√	6 – 20	0.6 – 1.0 H	Small - medium	N/A

Notes:

(1) Height range given is for wall with anchors.
(2) For solider pile and lagging wall only. Permanent facing adds significant cost.
(3) ROW requirements expressed as the distance (as fraction of wall height, H) behind the wall face where wall anchorage components (i.e. ground anchors and soil nails) are installed.
(4) ROW required if wall includes anchors.

Table 2. System Selection Chart for Cut Walls (Cont'd).

Wall Type	Advantages	Disadvantages
Sheet-pile wall	Rapid construction Readily available	Difficult to construct in hard ground or through obstruction
Solider pile/lagging wall	Rapid construction Solider beams can be drilled or driven	Difficult to maintain vertical tolerances in hard ground Potential for ground loss at excavated face.
Slurry (diaphragm) wall	Can be constructed in all soil types or weathered rock Watertight Wide range of wall stiffness	Requires specialty contractor Significant spoil for disposal Requires specialized equipment
Tangent pile wall	Adaptable to irregular layout Can control wall stiffness	Difficult to maintain vertical tolerances in hard ground Requires specialized equipment Significant spoil for disposal
Secant pile wall	Adaptable to irregular layout Can control wall stiffness	Requires specialty contractor Significant spoil for disposal
Soil mixed wall	Adaptable to irregular layout	Requires specialty contractor Relatively small bending capacity
Anchored wall	Can resist large horizontal pressures Adaptable to varying site conditions	Requires skill labor and specialized equipment Anchors may require permanent easements
Soil nailed wall	Rapid construction Adaptable to irregular wall alignment	Nail may require permanent easement Difficult to construct and design below water table
Micropile wall	Does not require excavation	Requires specialty contractor

DESIGN OVERVIEW

The purpose of this section is to present an overview of the design of earth retaining systems. It is not the intent of this section, nor is sufficient information presented, to enable the user to carry out detailed analysis and design for any of the earth retaining systems discussed. The reader is directed to appropriate references for detailed design and analysis procedures.

A general design methodology is outlined below. Step (1) involves establishing overall geometric requirements for the wall application and project requirements and constraints. This involves developing the wall profile, locating wall appurtenances such as traffic barriers, utilities, and drainage systems, establishing right-of-way (ROW) limitations, and construction sequencing requirements. Project requirements and constraints may significantly affect design, construction, and cost of the wall system and should therefore be identified during the early stages of project implementation. Step (2) involves wall system selection; Step (3) includes evaluating geotechnical properties necessary for wall design; Steps (4) through (9) address specific geotechnical and structural design requirements.

GENERAL DESIGN STEPS

The design of wall systems should follow a systematic process applicable for all wall systems and summarized below:

1. Basic Project Requirements: This includes determination of wall alignment, wall geometry, wall function, aesthetic, and project constrains (e.g. right of way, easement during construction, environment, utilities, etc.) as part of the wall development process.
2. Wall selection: Select wall type based on step 1.
3. Geotechnical Investigation: Subsurface investigation and analyses should be performed in accordance the Materials Division Manual of Instruction. This work generally requires preliminary evaluations performed in step 8 based on steps 5 thru 9.
4. Develop soil strength parameters.
5. Determine all applicable loads likely to act on the wall.
6. Initial wall sizing: This step requires initial sizing of various wall components.
7. Wall Design Requirements: Design wall systems using design standards and service life criteria and AASHTO Load and Resistance Factor Design requirements.
8. Perform external stability, overall stability, and wall movement checks. These checks will be wall specific and generally performed by the Designer. The stability should be performed using the performance limits, load combinations and load/resistance factors per AASHTO LRFD requirements.
9. Perform internal stability and structural design or the internal wall components and miscellaneous components. The designer for non-proprietary walls performs these computations. For proprietary walls, internal stability is the responsibility of the contractor/supplier after letting.

WALL SETTLEMENT MONITORING REQUIREMENTS

Excessive settlement can adversely affect both the performance and appearance of retaining walls. Both short term and long term settlement of retaining walls should be considered in design. Tolerable total and differential vertical deformations for a particular retaining wall are dependent on the ability of the wall to deflect without causing damage to the wall elements or adjacent structures, or without exhibiting unsightly deformations.

The following table provides guidance for maximum tolerable total and differential settlement for various retaining wall types. The tolerances provided are for guidance only. More stringent tolerances may be required to meet project-specific requirements

Settlement and Differential Settlement Tolerance

Wall Type	Total Settlement △h (inches)	Differential Settlement Tolerance(1)
Concrete gravity wall	1 - 2	1/500
Concrete cantilever wall	1 - 2	1/500
Concrete counterfort wall	1 - 2	1/500
Concrete crib wall	1 - 2	1/300
Gabion wall	4 - 6	1/50
MSE walls with small pre-cast panel facings (panel front face area $\leq$ 30 ft^2) joint width: ¾″	2 - 4	1/100
MSE walls with large pre-cast panel facing (panel front face area 30 ft^2 < area $\leq$ 75 ft^2) joint width: ¾″	2 – 4	1/200
MSE wall with modular block facing	2 - 4	1/300
MSE wall (geotextile/geogrid/welded wire facing)	4 - 8	1/60
Reinforced Soil Slopes (RSS)	<12	1/60

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

The designer must determine the maximum amount of settlement that can be allowed for a retaining wall to remain functional and what differential settlement can be tolerated before damage may begin to control.

Once these limits have been established, the designer shall set up a settlement monitoring program to ensure the acceptable limits will not be exceeded during the life of the structure.

The following chart establishes four levels of monitoring programs. Using the appropriate case the designer in coordination with the geotechnical engineer
will set the parameters for the contractor to follow during wall construction.

A settlement evaluation shall be performed for all walls.

The level of wall monitoring required is described below.

Case	Description of Settlement Cases	Level of Monitoring Required
1	If the calculated total elastic and consolidation settlement caused by wall construction over the life of the wall is less than ½ inch, or if the wall is on rock.	No monitoring is required.
2	If the calculated total elastic and consolidation settlement caused by wall construction over the life of the wall are: a) for abutments, less than 1 inch, and b) for roadway walls, 2 inches or less.	Settlement monitoring is required during the wall construction. Additional readings shall be taken for 30 days and at the completion of the project.
3	If the calculated elastic and intermediate consolidation settlement caused during the construction of the wall are less than 1 inch and the calculated remaining (Residual) elastic and/or consolidation settlement after wall completion are estimated to be less than 1 inch for abutments or 2 inches for roadway walls.	Settlement monitoring is required during the wall construction. Additional readings shall be taken for 60 days and at the completion of the project.
4	If the calculated elastic and intermediate consolidation settlement caused during the construction of the wall are greater than 1 inch and the calculated remaining (Residual) elastic and/or consolidation settlement after wall completion are estimated to be less than 1 inch for abutments or 2 inches for roadway walls.	Settlement monitoring is required during the wall construction and shall continue for the required “waiting” period. The construction of settlement critical items (approach slabs, moment slabs, and final paving) shall not take place until the Engineer of Record validates the required level of settlement has been reached. Additional readings shall be taken at the completion of the project.
5	If the calculated elastic and intermediate consolidation settlement caused during the construction of the wall are greater than 1 inch and the calculated remaining (Residual) elastic and/or consolidation settlement after wall completion are estimated to be greater than 1 inch for abutments or 2 inches for roadway walls.	Settlement monitoring is required during the wall construction and shall continue for the required “waiting” period. The construction of settlement critical items (approach slabs, moment slabs, and final paving) shall not take place until the Engineer of Record validates the required level of settlement has been reached. Additional readings shall be taken at the completion of the project.

The following table and notes shall be placed on the plans.

ESTIMATED WALL SETTLEMENT FOR *structure unit*

Monitoring Location	Estimated intermediate settlement at the end of wall construction (inches)	Estimated total settlement over the life of the wall (inches)	Estimated time for percent settlement to occur (days)				Required Waiting Period (days)
			25%	50%	75%	95%	

Total settlement is the settlement that occurs due to the placement of the wall between the beginning of wall construction and the end of design wall life.

Intermediate settlement is the settlement that occurs between the beginning of wall construction and the completion of the wall.

Settlement pins (or approved elevation monitoring devices) shall be attached along the face of the wall in readily accessible locations. A minimum of three monitoring pins shall be used: one at each end of the wall and one in the center of the wall. Pins shall also be placed when the increase in wall height from the previous pin exceeds 10 feet or as directed by the plans or the Engineer. Pin placement shall take into consideration the elevation of the finished ground line in front of the wall. The pins shall be protected from damage due to construction equipment.

As soon as the wall footing/leveling pad are in place, an elevation shall be taken. This will be considered the beginning of wall construction and will serve as the “baseline” for future settlement readings.

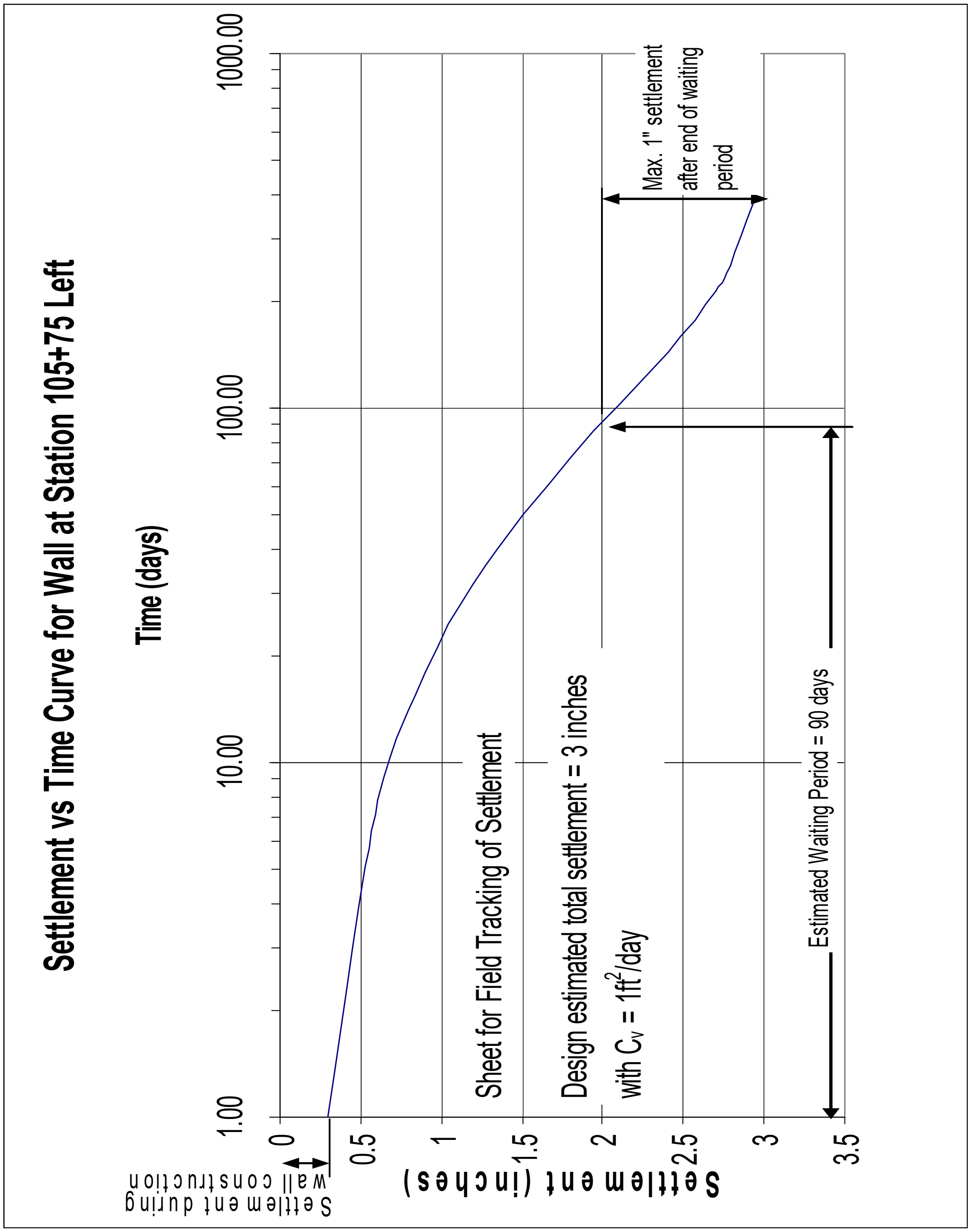
When the wall is above the proposed ground line, pins shall be installed and the elevation of each pin shall be surveyed. The elevation of the settlement pins shall be taken at least twice weekly until the full height of the wall is achieved, including wall backfill. This point will be considered the beginning of the “waiting period”.

The settlement monitoring frequency shall then be adjusted to once weekly. It shall continue at this frequency until the required waiting period has been completed and the Geotechnical Engineer of Record evaluates the data and confirms that: 1) the rate of settlement has stabilized; 2) the primary consolidation or elastic settlement is complete; and 3) the remaining long-term settlement will not exceed the allowable amount.

Survey readings shall be provided within 3 days to the Engineer for evaluation and disposition. The Engineer may change the frequency of the settlement readings, the settlement estimate and the mandated “waiting” period if the plan stated estimates do not reflect the actual field measurements.

The elevations for all pins shall be taken when all project construction is completed and results placed in the as-built plans.

Example of SETTLEMENT versus TIME Curve



MECHANICALLY STABILIZED EARTH (MSE) WALLS

GENERAL INFORMATION

MSE walls provide a cost effective alternative to reinforced concrete or gravity type walls traditionally used for soil retention in fill wall applications. They are particularly suited to economical construction in areas of poor soil conditions, offering significant cost savings over conventional reinforced concrete walls by eliminating costs related to piles, pile caps and other types of foundation improvements. They can also tolerate much larger settlements than reinforced concrete walls.

MSE walls consist of three major components: reinforcing elements, facing system and reinforced backfill. MSE walls can be classified according to their facing system in the following three types:

- Precast concrete panel facing
- Segmental modular block facing
- Geotextile/geogrid/welded wire fabric facing

The most common type of MSE wall used in transportation applications is the precast concrete panel facing MSE wall. Because of lack of aesthetic facing, geotextile/geogrid/welded wire facing MSE walls are typically used for temporary applications.

Most precast concrete panel systems employ metallic (steel strips or steel grids) reinforcement that is connected to a precast concrete panel to create a reinforced soil mass. Modular block wall systems typically employ geosynthetic reinforcement, predominantly geogrids, that is secured between the blocks at predetermined levels and extend into the granular soil backfill.

The backfill material shall be of high quality for durability, good drainage, constructability and good soil reinforcement interaction which can be obtained from well graded, granular materials. For walls with metallic strips, the load is transferred from the backfill soil to the strip reinforcement by shear along the interface. For walls with steel grids, the load is similarly transferred but an additional component of strength is obtained through the passive resistance on the transverse members of the reinforcement. For walls with geogrid reinforcement, the load is transferred from the soil to the reinforcement through passive resistance on transverse members of the grid and interface friction between the soil and the surface of the reinforcement.

MSE walls offer the following advantages over conventional reinforced concrete and concrete gravity walls:

- Wall system construction is relatively rapid and does not require specialized labor or equipment.
- Requires less foundation preparation.
- Wall system is flexible and can accommodate relatively large total and differential settlements without distress.
- Reinforcement is light and easy to handle.
- Concrete facing panels permit greater flexibility in the choice of facing and architectural finishes.

- Since wall system is flexible, it is well suited for applications in regions of high seismicity.
- Need less space in front of structure for construction operations.
- Reduce right-of-way acquisition.
- Do not require rigid, unyielding foundation support due to their tolerance to deformations.
- Are cost effective for walls taller than about 10 ft.
- Are technically feasible to heights in excess of 100 ft. However, MSE walls are generally considered for heights ranging from 10 – 65 feet. For heights exceeding 65 feet, or where compressible materials are present, special considerations will be required.

Some potential disadvantages of MSE walls are:

- They require a relatively large space behind the wall to install reinforcement.
- Wall system may not be economical for cut applications due to additional cost associated with constructing temporary excavation support to provide enough base width.
- Use of metallic reinforcement requires that backfill meet minimum electrochemical requirements for corrosion protection.
- Strength of geosynthetic reinforcement must be reduced to account for creep, durability, and construction damage.
- Wall system may not be appropriate for applications where it may be necessary to gain future access to underground utilities, at locations subject to scour, or involving significant horizontal curvature (segmental precast concrete panel MSE walls).
- At some sites, the cost of importing suitable backfill material may render the system uneconomical.

Typical applications of MSE walls in transportation projects include:

- Retaining walls
- Bridge abutments and wingwalls
- Access ramps
- Slope stabilization
- Waterfront structures
- Support of temporary roadway embankments
- Temporary support of permanent roadway embankments for phased construction

GENERAL DESIGN REQUIREMENTS

The design of retaining walls consists of two principle parts: the evaluation of loads and pressures that act on the structure, and the design of the structure to withstand these loads and pressures within acceptable tolerable deformations.

Retaining walls shall be investigated for the following:

- Lateral earth and water pressures, including dead and live load surcharges
- Dead load of the wall
- Vehicular or other impact loading
- Loads applied from the superstructure
- Temperature and shrinkage deformation effects
- Seismic loads

The design shall be investigated for any combination of forces which may produce the more severe loading condition.

Mechanical Stabilized Earth (MSE) Walls:

The following general considerations should be given to the evaluation and use of MSE walls:

- Project location and site-specific conditions
- Economics
- Construction Requirements
- Aesthetics

Unless a design approval is granted by the District Structure and Bridge Engineer (DBE):

- MSE walls are prohibited in karst areas. Where design approvals are sought, the subsurface conditions shall be investigated more thoroughly than what is typically performed at sites where karst conditions are not present. The subsurface investigation in karst areas will likely involve the use of a greater number of SPT borings and/or CPT probes, as well as the use of geophysical testing (e.g., electrical resistivity) to better map the subsurface conditions.

- MSE walls are prohibited in flood plains and tidal areas. Where design approvals are sought, special considerations will be required. These special considerations include, but are not limited to, the use of a free-draining select backfill material within the reinforced mass and geosynthetic fabric to separate the reinforced mass from the retained soil.

Additional consideration must be given to MSE walls placed within the vicinity of utilities, including pressurized water and sewer mains.

MSE walls are generally considered for heights ranging from 10 – 65 feet. For heights exceeding 65 feet, or where compressible materials are present, special considerations will be required. These special considerations include, but are not limited to, the use of ground improvement methods such as wick drains, surcharge loading, over-excavation, or stone column soil reinforcing.

Backfill material and placement requirements for use with MSE walls shall be in accordance with the project specific Special Provisions. For a full list of VDOT approved Retaining Wall Systems and manufacturers, refer to File No. 18.06.1.

When MSE walls are used in conjunction with moment slabs and traffic barriers, the designer shall refer to the requirements of NCHRP Report 663, *Design of Roadside Barrier Systems Placed on MSE Retaining Walls*, including Appendix I, *AASHTO LRFD Format Design Guideline.*

For additional considerations for the use of MSE walls in conjunction with bridge abutments, refer to Chapter 17, File Nos. 17.01-7 thru 17.01-9.

GUIDELINES FOR THE PREPARATION OF MSE WALL PLANS

1. Review road plans and cross-sections to estimate approximate wall location, height and length of reinforced soil mass.

   a. Check that the entire wall (including the reinforced mass) is located within the Department's right-of-way (R/W). If the wall is outside the R/W limits, determine if it is feasible to acquire additional R/W or underground easement.

   b. Check if any utilities or obstructions located within the reinforced soil mass can be adequately accommodated within the requirements and limitations of the proposed systems allowed for construction.

   c. Fill out Form LD-155 and send it to VDOT Central Office, Structure and Bridge Division Geotechnical Section. The form can be downloaded from http://vdotforms.vdot.virginia.gov/SearchResults.aspx?strFormNumber=LD-155.

2. Review the geotechnical information (geotechnical reports, boring logs, laboratory test data, etc.) and estimate the location of the proposed bearing stratum.

3. Perform bearing resistance calculations to determine the factored soil bearing resistance at the estimated bearing stratum. The factored soil bearing resistance must be stated on the plans.

4. Determine the anticipated loading condition (level backfill, level backfill with traffic surcharge, sloping backfill, or sloping backfill with traffic surcharge, etc.).

5. Calculate the maximum factored bearing pressure that the wall will impose on the soil. If the maximum factored bearing pressure imposed by the wall is less than the factored soil bearing resistance calculated in Step 3, the bearing resistance requirements are satisfied.

6. Perform settlement calculations to determine total and differential settlements. In addition to the magnitude of settlement, an estimate of the time-rate of settlement shall be performed. Wick drains, surcharge loading, or some other method of ground improvement may be required to limit post wall construction settlements to an acceptable amount. Check the angular distortions to determine if they appear to be within allowable limits per AASHTO.

   a. Evaluate whether a waiting period for installing coping, parapet, barrier, moment slab, piles, paving etc. is required after wall completion.

   b. The estimated remaining settlement following any applicable wait period shall not exceed 1 inch for walls at abutments and for walls within 100 feet of abutments, and 2 inches for walls beyond 100-feet of abutments, for the remaining design life of the wall.

   c. The Engineer may change the frequency of the settlement readings, the settlement estimate and the mandated "waiting" period if the plan stated estimates do not reflect the actual field measurements.

   d. A Settlement versus Time curve shall be developed and used in tracking actual field measured settlements (See File 18.01-12 for example).

   e. Walls with more than 4 inches of calculated total settlement must receive approval from the Structure and Bridge Geotechnical Program Manager.

7. Calculate eccentricity of loading (overturning), sliding, and overall stability for the applicable loading conditions. If the eccentricity limit according to AASHTO is greater than the eccentricity of loading, the factored resistance against sliding failure is greater than the factored sliding force, and the factor of safety for overall stability is greater than required, the overturning, sliding, and overall stability requirements are satisfied.

8. Evaluate the site for potentially deleterious environmental factors such as corrosive groundwater, seepage forces, stray currents, etc. which may adversely affect the wall.

   If all of the external stability issues described above (bearing resistance, settlement, overturning, sliding and overall stability requirements) are satisfied, MSE walls may be used at this location. If any of the above is not satisfied, ground modification or a different type of retaining wall may be required.

9. If an MSE wall is feasible, determine the wall geometry (stationing and offsets).

10. Determine the top-of-wall elevations at intervals not exceeding 50 ft. This can be accomplished using roadway information such as road plans, profiles, cross-sections, and the like. The top of wall shall be either the top of coping or the top of the moment slab (whichever is applicable).

11. Determine the bottom-of-wall elevations at the same locations (stations) that the top-of-wall elevations were found in Step 10. Check that there is adequate embedment at the toe of the wall in accordance with AASHTO and that the embedment satisfies overall stability requirements. The bottom of wall shall be taken to be the top of the leveling pad.

12. Check that the top and bottom elevations of the wall determined in Steps 10 and 11 are within the limits assumed in Step 1. If not, recalculate the bearing resistance, settlement, eccentricity of loading, sliding, and overall stability to be sure that the external stability of the wall is adequate.

13. Draw the Elevation View (or “Three-Line Drawing”) showing the top of wall, bottom of wall, and the approximate finished grade adjoining the front face of the wall. Show stations and elevations. Show the locations of all pipes and utilities that will be penetrating the wall or behind the panels, so the selected wall company can design for those conditions.

14. Draw the Plan View. Show stationing, offsets, boring locations (if not already shown on the bridge substructure layout), and all pipes and utilities in the vicinity of the wall.

15. If included in the project scope, architectural treatment and details shall be included on the drawings.

16. Draw Typical Sections for all significantly different wall sections. For each section, show the limits of payment, the required slope in front of the wall, the required slope of the backfill, and all special loading conditions. The limits of payment shall be shown to extend from the top of the wall (top of coping or moment slab) to the bottom of the wall (top of the leveling pad).

17. If soil reinforcement length longer than the AASHTO minimum requirement is needed for bearing resistance or overall stability reasons, it shall state the required minimum length on the plans.

18. Calculate the surface area of the wall based on top and bottom wall elevations and show this quantity on the plans (Square Feet, ⊗ Plan Quantity Item). When required, the traffic barrier / parapet shall be listed as a separate payment item (Linear Feet, ⊗ Plan Quantity Item). Payment (if any) for additional square footage of wall created by the settlements should be addressed in the contract documents.

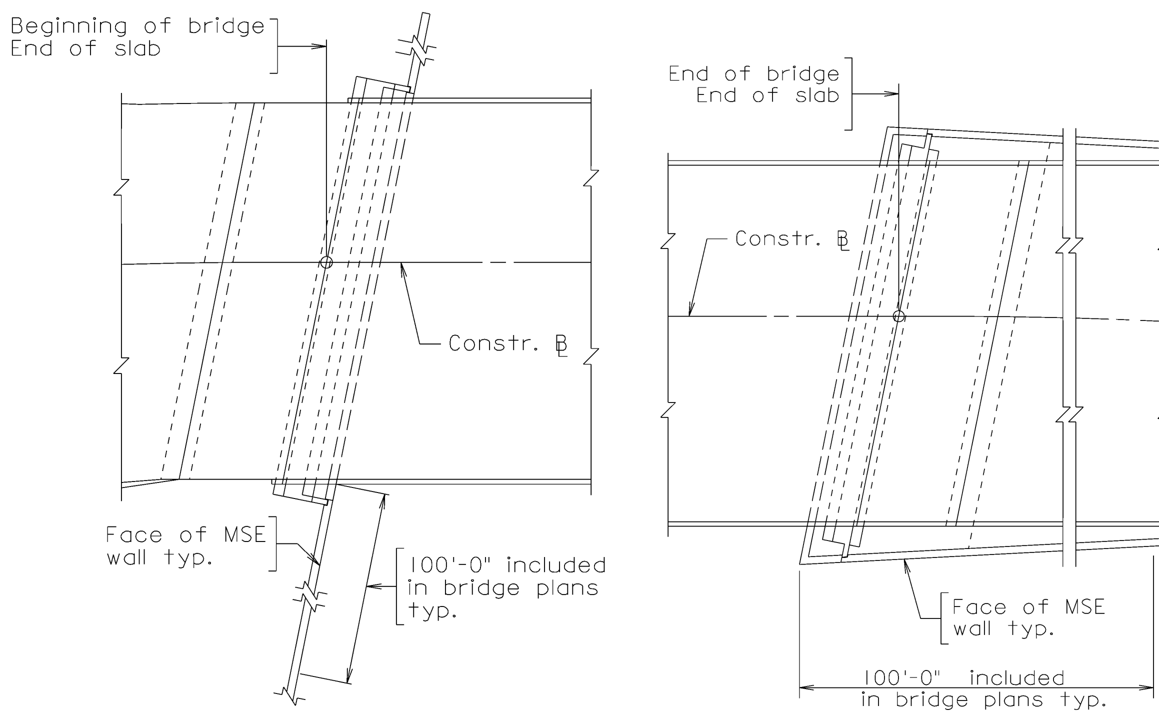
19. The plans shall clearly indicate whether some method of ground improvement is required and the manner in which the Contractor will be paid for this work. If over excavation and replacement is required, these items shall be listed as separate payment items [Undercut Excavation, (Cubic Yards)] and [Select Material Type I, Minimum CBR of 30 (tons)]. The estimated limits of undercut and backfilling shall be indicated on the Elevation View and the Typical Sections.

20. List the approved wall companies with their addresses and telephone numbers on the plans so the Contractor can contact them to request bids. Some projects have geometric constraints (e.g., walls that wrap around bridge abutments) that preclude the use of some wall systems. Wall systems that cannot conform to the geometrics of the project shall not be included on the plans as an allowable wall system.

21. Include the boring logs (Geology Sheets) in the plans.

22. Place appropriate Notes on the plans.

23. Plans for retaining walls that are under the bridge and within 100 feet as shown below shall be included in the bridge plan set.



NOTES FOR MSE WALL PLANS

These are suggested wordings for notes that are regularly or occasionally needed. Where these notes are fully applicable, there may be no need to change their wording. They should be changed, however, or other notes added, wherever they are not adequate.

Notes should line up with the MSE Wall Notes in the upper right-hand corner of the plan sheet.

Notes in the single parentheses indicate alternate wordings to be selected by the designer. Notes in the double parentheses *((italics))* are explanations and instructions to the designer. Skip a line between paragraphs.

MSE Wall Notes:

The minimum design life of MSE wall shall be (75-year) (100-year).((*All MSE walls at the following locations shall be designed for a 100-year service life with respect to soil reinforcement design: 1) walls greater than 30 feet in height, 2) walls in front of bridge abutments, 3) walls within 100 feet from edge of a bridge abutment or pier, or 4) walls located above or below interstates roadways and ramps and urban principle arterial roadways and ramps.*))

The anticipated MSE wall total settlement is ____ inches and differential settlement is _____. *((Add table if settlement varies along wall alignment.))*

For bearing resistance requirements, see the MSE Wall Bearing Resistance Data Table.

For settlement requirements, see the Estimated Wall Settlement Table.

Vertical slip joints shall be placed in the wall at intervals not to exceed ____ ft. between Stations __________ and _________.

Prior to wall construction, the foundation shall be compacted with a smooth wheel vibratory roller weighing 10 tons minimum. The drums of the roller should be ballasted, and each pass of the roller should overlap one half the width of the previous pass. The roller shall make at least ten passes over the proposed wall foundation zone. No density test will be required. Any foundation soils found to be unsuitable and/or unstable shall be removed and replaced with select material Type I minimum CBR of 30. Compact the foundation area according to the VDOT Specifications. *((Use note where marginal foundation conditions exist or zones of unsuitable material maybe encountered.))*

Remove unsuitable or unstable foundation material below the bottom of the wall and replace with select material prior to wall construction. Compact the foundation area according to the VDOT Specifications.

The minimum required depth of undercut shall be _____ ft. between Stations _________ and _________. *((Add table if undercut depth varies along wall alignment.))*

The estimated required depth of unsuitable material to be removed is shown on the plans. The lateral limits of excavation are dependent on the depth at a particular location below the wall. Additional localized excavation may be required depending on the site conditions at the time of construction.

Minimum panel design thickness is 5.5 inches. Thickness of concrete must increase to accommodate any architectural surface finish that may be specified.

Concrete in moment slabs and parapet/railing shall be Low Shrinkage Class A4 Modified.

Corrosion Resistant Reinforcing (CRR) steel shall be used in moment slab and shall be the same type of corrosion resistant reinforcing steel specified for parapet / railing.

Class I CRR steel shall be used in copings. ((*Class I CRR steel is required per current VDOT S&B Instructional and Informational Memorandum Number 81*)).

Class I CRR steel shall be used in portions of MSE Wall panels within splash zone as shown on plans. ((*Class I CRR steel is required in MSE Wall panels within the splash zone per current VDOT S&B Instructional and Informational Memorandum Number 81*)).

Architectural treatment shall be ______________.

Concrete surface coating shall be _______, similar to Federal Standard Color No. _______.

An impervious membrane shall be placed below the pavement and just above the first row of reinforcement. The membrane shall be sloped to drain away from the facing to an intercepting longitudinal drain outlet beyond the reinforced zone. ((*Used when the extensive use of deicing chemical may cause accelerated corrosion problems*)).

A non-woven geotextile shall be used as a separator between the mechanically stabilized earth mass and the subbase. ((*Used where the potential for the subbase migration into an oversized selected material may occur*)).

(Coping) (parapet) (railing) (barrier) (moment slab) (piles) (paving) shall not be placed until _____ days after wall completion have elapsed.

The selected wall supplier will submit a detailed design and shop drawings for approval.

Provide drainage details such as perforated pipe underdrain and/or drainage blanket based upon field conditions. For wall installation at stream crossing, provide adequate drainage so the difference between streambed and saturated backfill is not greater than what is considered in the design.

All panel types and other related elements shall be detailed on shop drawings.

Format to be placed on the plans:

MSE WALL BEARING RESISTANCE DATA TABLE		
Support Location	**Service** Applied Base Pressure (Settlement = X") (ksf)	**Strength** Factored Bearing Resistance φ_b = Y (ksf)

The wall design shall be based on the lower of the values (either Service Limit or Strength Limit States) given for each Support Location in the table above. The Nominal Bearing Resistance will be verified by the engineer prior to construction of wall.

MSE WALL LAYOUT AND DETAILS

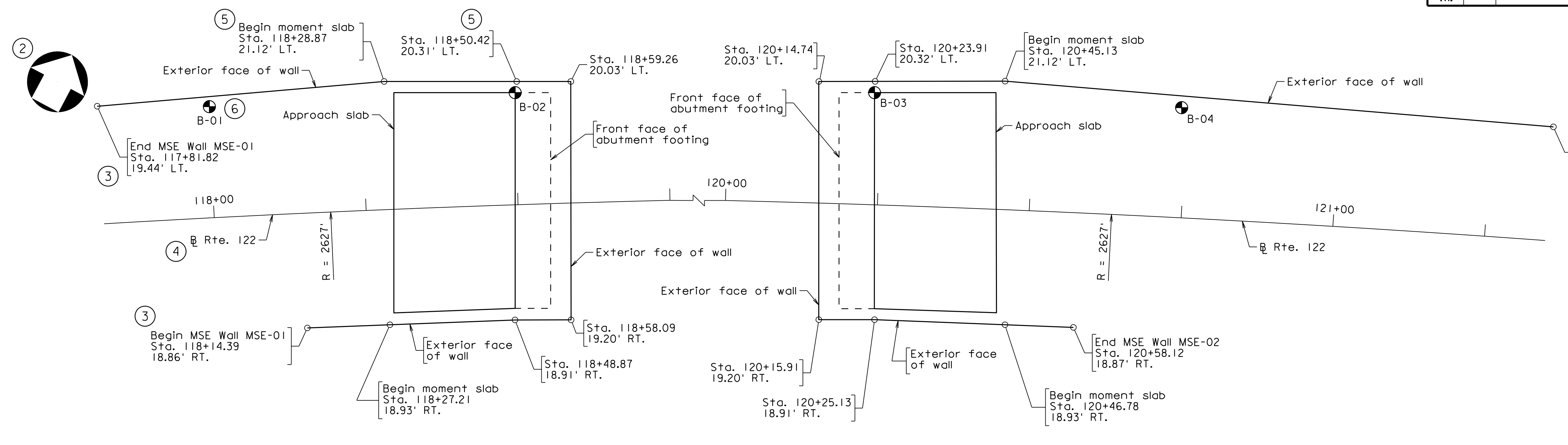
MSE Wall Layouts for Bridges:

The presentation of MSE walls shall include plan view, developed elevation, estimated wall settlement table, bearing resistance table, notes, approved list and other relevant information. The plan view should use single solid line to present the layout and indicate stations, skew and other relevant information. The boring locations should be indicated in the plan view too. The developed elevation should be presented with three line diagram (TLD). A TLD consists of Top of coping, Proposed ground line and Top of leveling pad. The stations and elevations at the controlling points, and the existing ground line should be shown on the developed elevations.

These plan sheets should be included in the bridge plans following the approach slab plans or engineering geology sheets whichever applicable as indicated in File 01.02-4.

File No.s 18.05-2 thru -4 illustrate basic elements of an MSE wall presentation.

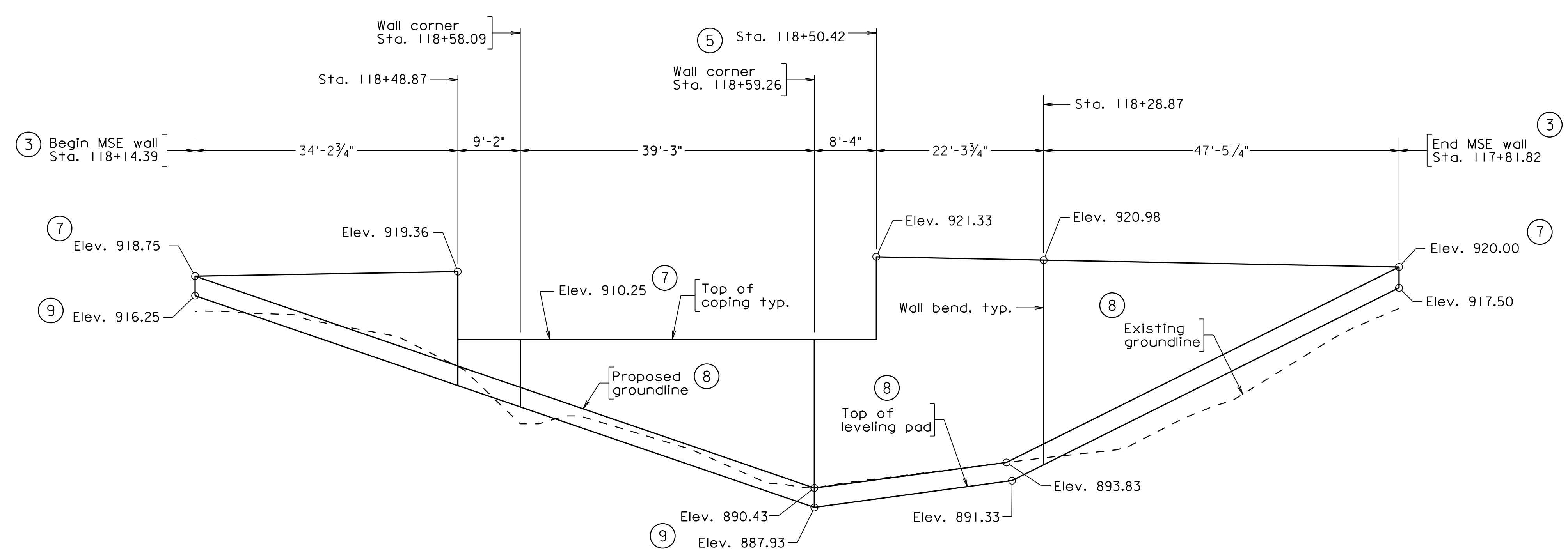
STATE	FEDERAL AID ROUTE	FEDERAL AID PROJECT	STATE ROUTE	STATE PROJECT	SHEET NO.
VA.	—		122	0122-033-733, B614	36



① PLAN

Legend:

Denotes boring location.



DEVELOPED ELEVATION MSE WALL MSE-01 ①

EARTH RETAINING WALLS
SAMPLE MSE WALL LAYOUT SHEET FOR ABUTMENTS

Scale: 1" = 10'

No.	Description	Date
	Revisions	

COMMONWEALTH OF VIRGINIA
DEPARTMENT OF TRANSPORTATION

STRUCTURE AND BRIDGE DIVISION

MSE WALL PLAN
AND MSE-01 ELEVATION

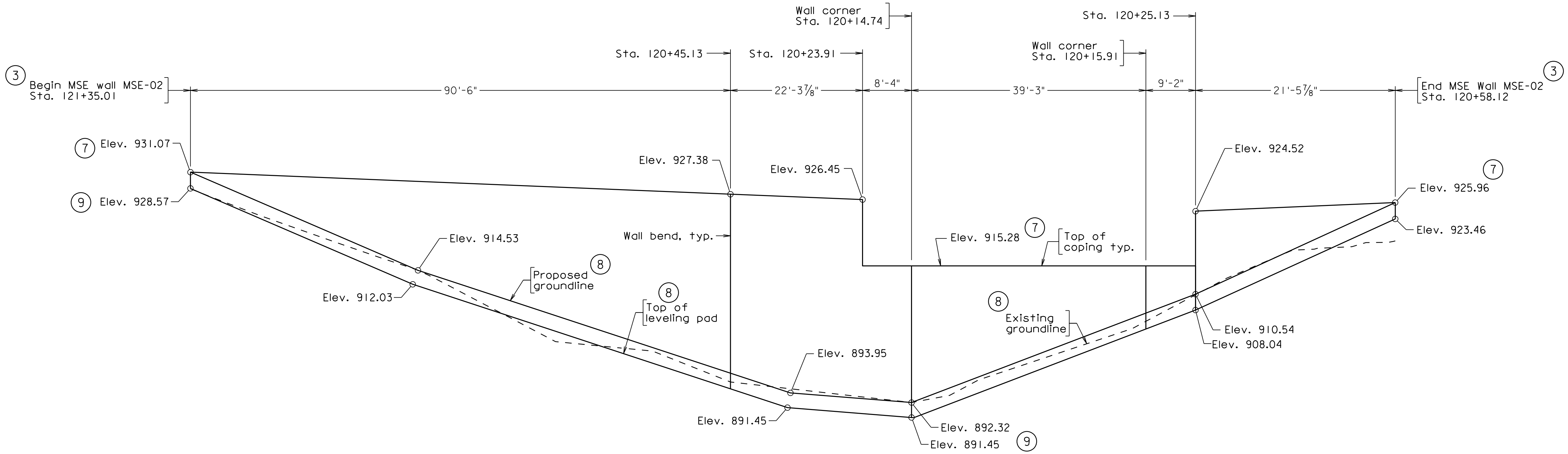
Designed: ABC
Drawn: DEF
Checked: GHI
Date: Apr. 2020
Plan: 999-

PART 2
DATE: 30Apr2020
SHEET 2
FILE NO. 18.05-2

VDOT S&B DIVISION
RICHMOND, VA
STRUCTURAL ENGINEER

999-90-036.dgn

STATE	FEDERAL AID		STATE		SHEET NO.
	ROUTE	PROJECT	ROUTE	PROJECT	
VA.	—		122	0122-033-733, B614	37



(1) DEVELOPED ELEVATION MSE WALL MSE-02

999-90-037.dgn

VDOT S&B DIVISION
RICHMOND, VA
STRUCTURAL ENGINEER

EARTH RETAINING WALLS
SAMPLE MSE WALL LAYOUT SHEET FOR ABUTMENTS

Scale: 1" = 10'

No.	Description	Date
	Revisions	

COMMONWEALTH OF VIRGINIA
DEPARTMENT OF TRANSPORTATION

STRUCTURE AND BRIDGE DIVISION

MSE-02 ELEVATION

	Date	Plan	
Designed: ABC Drawn: DEF Checked: GHI	Apr. 2020	999-	PART 2 DATE: 30Apr2020 SHEET 3 FILE NO. 18.05-3

ESTIMATED WALL SETTLEMENT TABLE							
Monitoring Location	Estimated intermediate settlement at the end of wall construction (inches)	Estimated total settlement over the life of the wall (inches)	Estimated time for % settlement to occur (days)				Required Waiting Period from Wall Completion (days)
			25%	50%	75%	95%	

Total settlement is the settlement that occurs due to the placement of the wall between the beginning of wall construction and the end of design wall life.

Intermediate settlement is the settlement that occurs between the beginning of wall construction and the completion of the wall.

Settlement pins (or approved elevation monitoring devices) shall be attached along the face of the wall in readily accessible locations. A minimum of three monitoring pins shall be used: one at each end of the wall and one in the center of the wall. Pins shall also be placed when the increase in wall height from previous pin exceeds 10 feet or as directed by the plans or the Engineer. Pin placement shall take into consideration the elevation of the finished ground line in front of the wall. The pins shall be protected from damage due to construction equipment.

As soon as the wall footing/leveling pads are in place, an elevation shall be taken. This will be considered the beginning of wall construction and will serve as the "baseline" for future settlement readings.

When the wall is above the proposed ground line, pins shall be installed and the elevation of each pin shall be surveyed. The elevation of the settlement pins shall be taken at least twice weekly until the full height of the wall is achieved, including wall backfill. This point will be considered the beginning of the "waiting period".

The settlement monitoring frequency shall then be adjusted to once weekly. It shall continue at this frequency until the required waiting period has been completed and the Geotechnical Engineer of Record evaluates the data and confirms that: 1) the rate of settlement has stabilized; 2) the primary consolidation or elastic settlement is complete; and 3) the remaining long-term settlement will not exceed the allowable amount.

Survey readings shall be provided within 3 days to the Engineer for evaluation and disposition. The Engineer may change the frequency of the settlement readings, the settlement estimate and the mandated "waiting" period if the plan stated estimates do not reflect the actual field measurements.

The elevations for all pins shall be taken when all project construction is completed and results placed in the as-built plans.

APPROVED RETAINING WALL SYSTEMS	
System	VENDOR
Reinforced Earth Walls	The Reinforced Earth Company 12001 Sunrise Valley Drive, Suite 400 Reston, VA 20191 (703) 547-8797 www.reinforcedearth.com
Retained Earth Walls	The Reinforced Earth Company 12001 Sunrise Valley Drive, Suite 400 Reston, VA 20191 (703) 547-8797 www.reinforcedearth.com
Reinforced Soil Embankment System	Hilfiker Retaining Walls 1902 Hilfiker Lane Eureka, CA 95503 (800) 762-8962 or (707) 443-5093 www.hilfiker.com
Vist-A-Wall Stabilized Earth Wall with Grid-Strip Reinforcing	Big R Bridge - Vist-A-Wall Systems 19060 County Road, Greeley, CO 80631 (800) 234-0734 www.bigrbridge.com
Isogrid Walls	The Neel Company 8328-D Traford Lane Springfield, VA 22152 (703) 913-7858 www.neelco.com
EarthTrac HA MSE	EarthTec, Inc. 413 Browning Court Purceville, VA 20132 (703) 771-7305 www.earthteccorp.com

MSE WALL BEARING RESISTANCE TABLE		
Support Location	SERVICE Applied Base Pressure (Settlement = X ") (ksf)	STRENGTH Factored Bearing Resistance (ksf)

Notes:

The minimum design life of MSE walls shall be 100-year.

For bearing resistance requirements, see the MSE Wall Bearing Resistance Data Table.

For settlement requirements, see the Estimated Wall Settlement Table.

Prior to wall construction, the foundation shall be compacted with a smooth wheel vibratory roller weighing 10 tons minimum. The drums of the roller should be ballasted and each pass of the roller should overlap one half the width of the previous pass. The roller shall make at least ten passes over the proposed wall foundation zone. No density test will be required. Any foundation soils found to be unsuitable and/or unstable shall be removed and replaced with select material Type I minimum CBR of 30. Compact the foundation area according to the VDOT Specifications.

Minimum panel design thickness is 5.5 inches. Thickness of concrete must increase to accommodate any architectural surface finish that may be specified.

Concrete in moment slabs and parapet shall be Low Shrinkage Class A4 Modified.

Corrosion Resistant Reinforcing (CRR) steel shall be used in moment slab and shall be the same type of corrosion resistant reinforcing steel specified for parapet.

Class I CRR steel shall be used in copings.

An impervious membrane shall be placed below the pavement and just above the first row of reinforcement. The membrane shall be sloped to drain away from the facing to an intercepting longitudinal drain outlet beyond the reinforced zone.

A non-woven geotextile shall be used as a separator between the mechanically stabilized earth mass and the subbase.

Coping, parapet and moment slab shall not be placed until 30 days after wall completion have elapsed.

The selected wall supplier will submit a detailed design and shop drawings for approval.

Provide drainage details such as perforated pipe underdrain and/or drainage blanket based upon field conditions. For wall installation at stream crossing, provide adequate drainage so that the difference between stream bed and saturated backfill is not greater than what is considered in the design.

All panel types and other related elements shall be detailed on shop drawings.

999-90-038.dgn

EARTH RETAINING WALLS
SAMPLE MSE WALL NOTES

VDOT S&B DIVISION
RICHMOND, VA
STRUCTURAL ENGINEER

No.	Description	Date
	Revisions	

COMMONWEALTH OF VIRGINIA
DEPARTMENT OF TRANSPORTATION

STRUCTURE AND BRIDGE DIVISION

MSE WALL NOTES

Designed: ABC
Drawn: DEF
Checked: GHI

Date: Apr. 2020

Plan: 999-

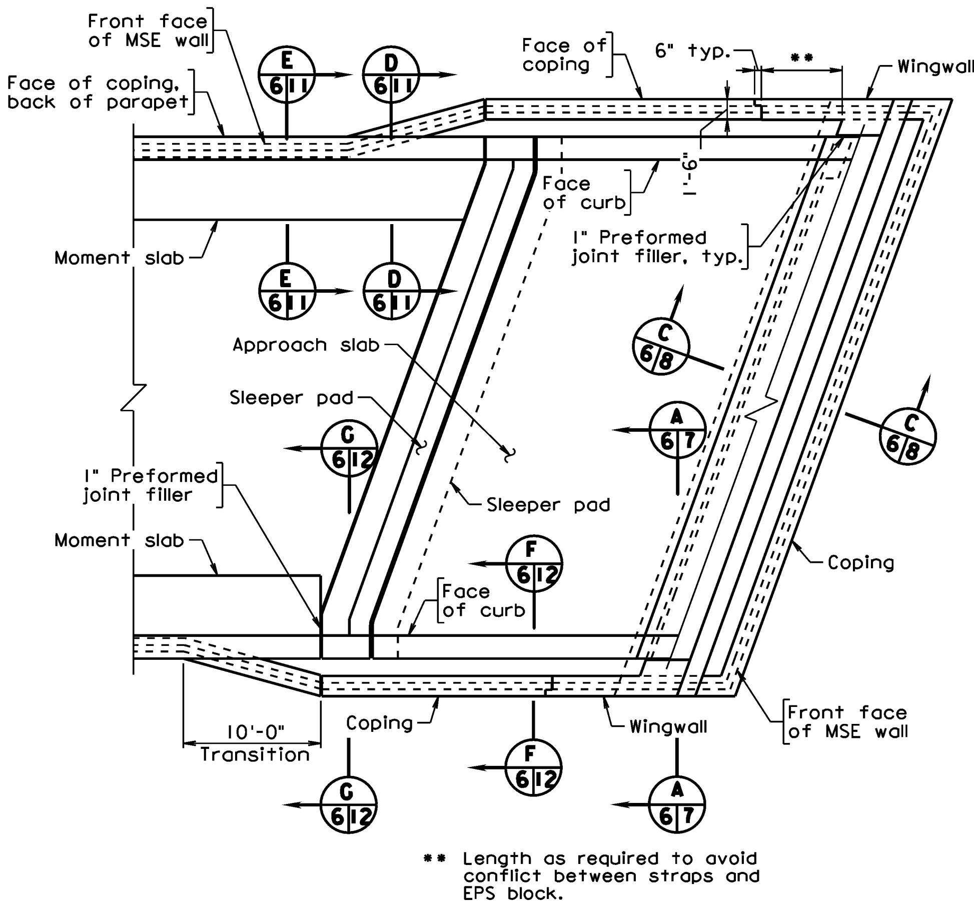
PART 2
DATE: 30Apr2020
SHEET 4
FILE NO. 18.05-4

Checklist for MSE Wall Three Line Diagram:

1. Label PLAN and DEVELOPED ELEVATION of MSE walls.
2. Show North Arrow on PLAN.
3. Label Begin and End of MSE wall and, if applicable, moment slab.
4. Label C/L or B/L as applicable, to match front sheet of bridge plans.
5. Provide station and offset from C/L at Beginning and End of MSE wall, wall corners, changes in wall alignment or wall height, and beginning of moment slab. Provide stations in ELEVATION.
6. Show boring log locations.
7. Label top of coping (or top of wall if no coping present). Provide top of coping elevations at Begin and End of MSE wall, at wall corners and at changes in wall alignment.
8. Label top of leveling pad, proposed groundline and existing groundline.
9. Show elevations of top of leveling pad and of proposed groundline.

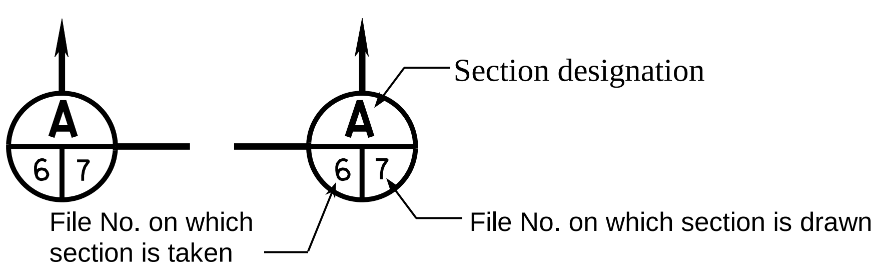
MSE Wall Layouts for Bridges (continued):

For some complex layouts of MSE wall and bridge, additional details may be needed. For example, if a project has moment slabs, approach slabs, tapering of MSE walls, unique interface of wingwall and MSE wall and so forth, a detailed plan view and sections may be necessary as shown in the following figures.

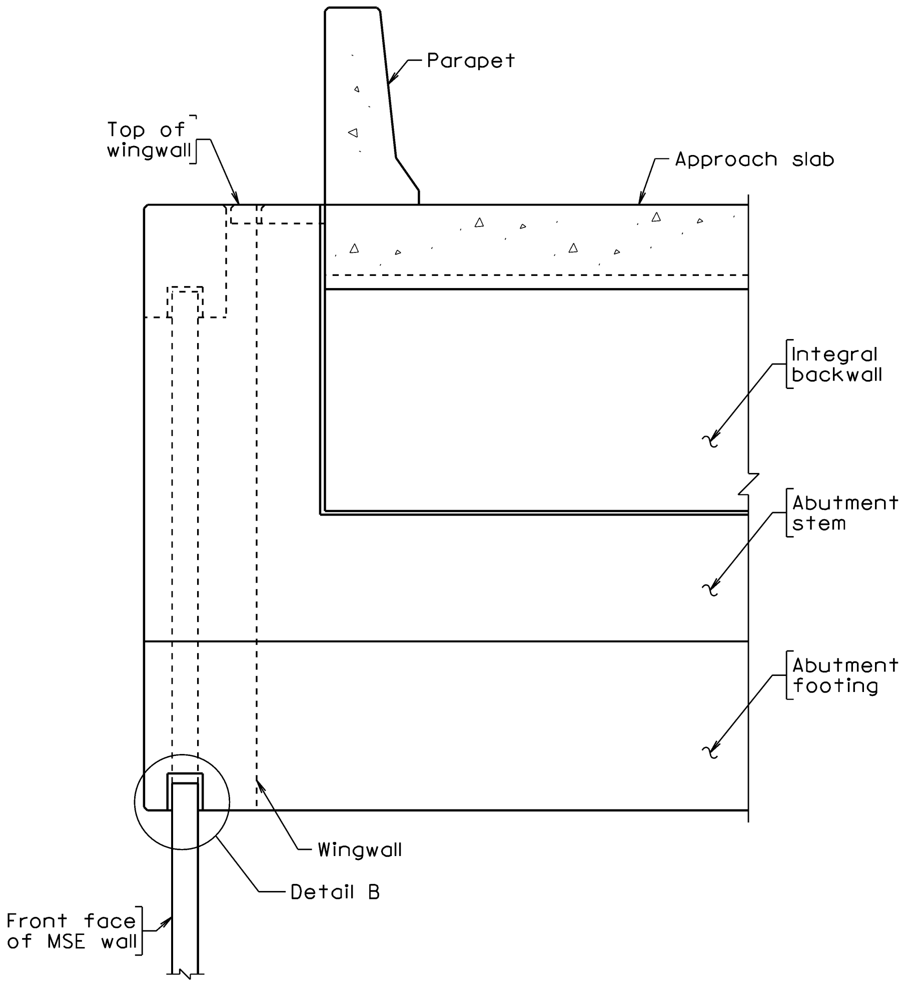


Part of Plan

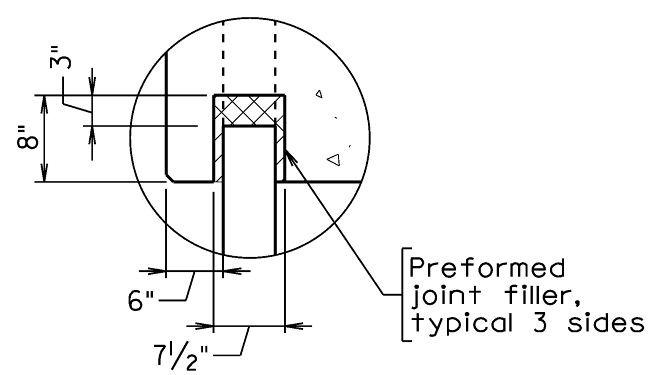
Notation:



MSE Wall Layouts for Bridges (continued):



Section A – A Taken from File No. 18.05-6

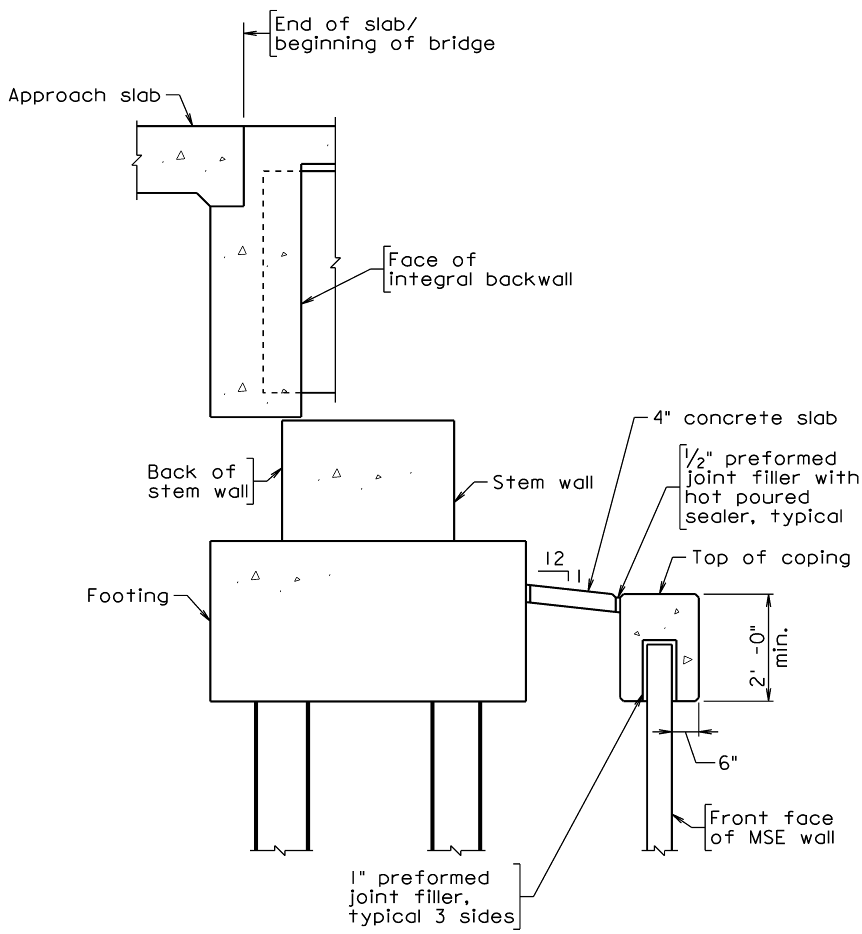


Detail B

The details of various MSE wall components are critical to the successful implementation of MSE wall projects. The following details have been used successfully in past projects. These details should be used to the maximum extent. They may need minor modifications to fit the requirements of specific projects.

MSE Front Walls for Abutments:

When MSE wall is used in front of abutment, the bridge superstructure and abutment shall be supported by deep foundations such as driven piles or drilled shafts. Vertical loads are not considered in analysis of MSE wall since they are transmitted to an appropriate bearing stratum by deep foundations. However, the horizontal bridge and abutment backwall forces shall be resisted by the lateral resistance of the deep foundations. The minimum distance between MSE wall panels and piling shall meet the requirements in File No. 17.01-7.

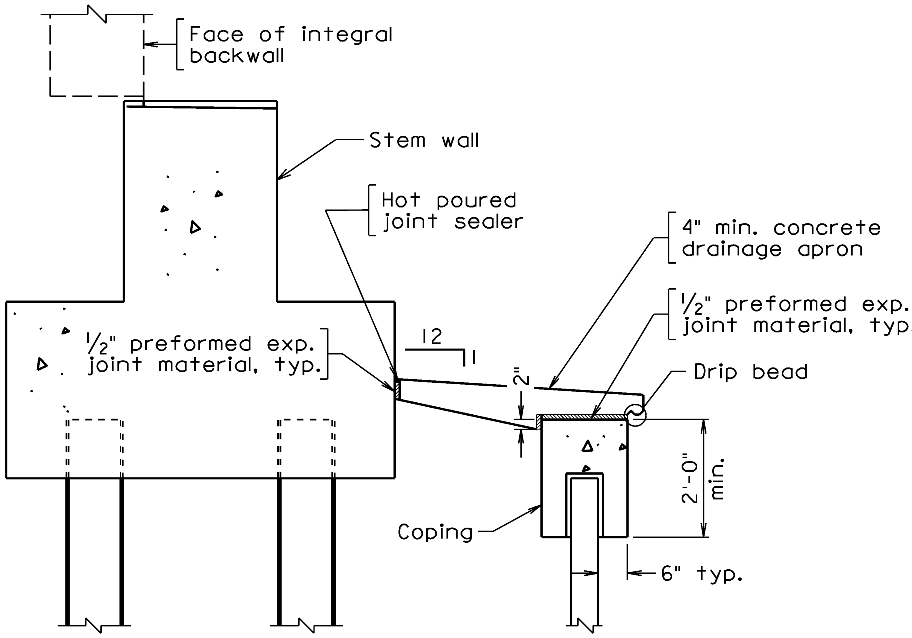


Section C – C Taken from File No. 18.05-6

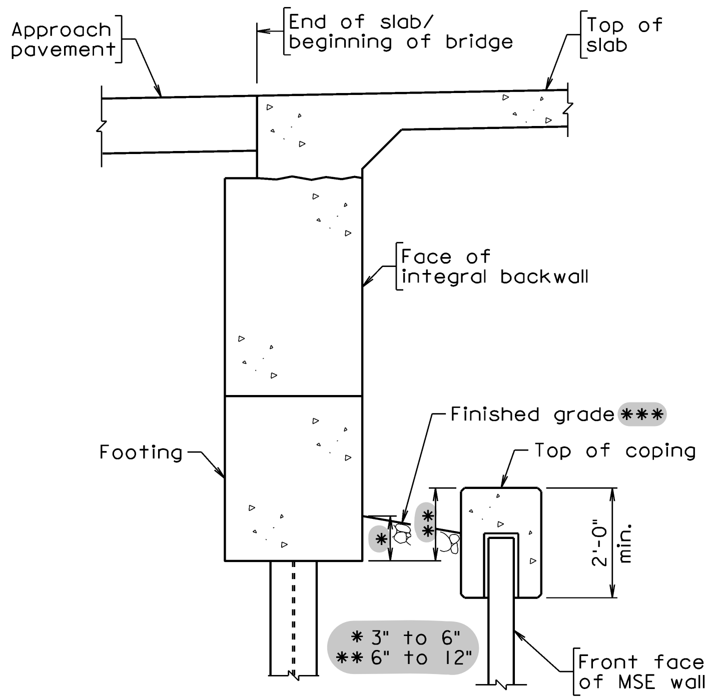
For full-integral abutment, the horizontal forces and its distribution with depth may be developed using a lateral load (p)-lateral deflection (y), i.e., p-y methods. These horizontal forces are added as a supplementary force to be resisted by the reinforcements.

MSE Front Walls for Abutments (continued):

The following detail may be used as an alternate for MSE wall in front of abutment.



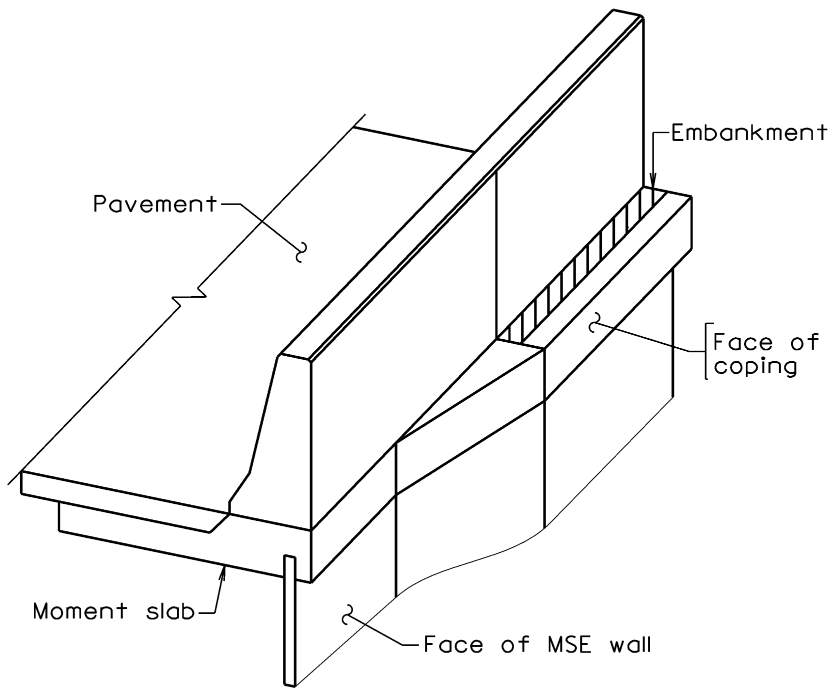
When MSE wall is used in front of a full-integral abutment, the following detail may be used.



*** If concrete slab slope protection is used in this area, refer to the detail on 18.05-8.
Increase thickness of preformed joint filler to accommodate thermal contraction of bridge.

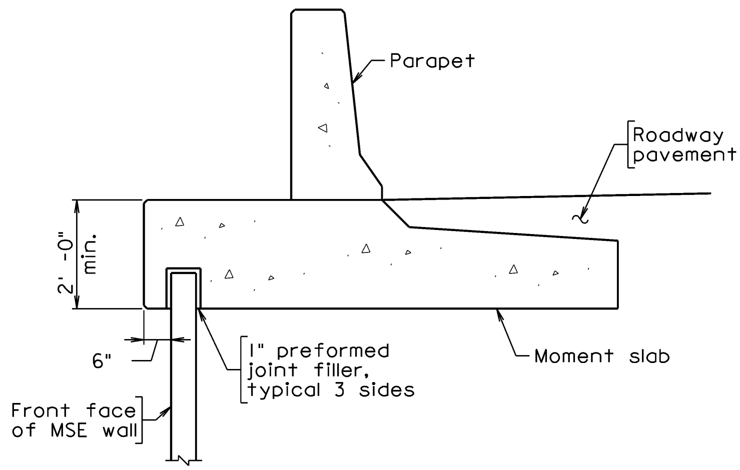
MSE Walls with Moment Slabs and Parapet:

Where concrete traffic barrier is used on MSE walls, moment slabs shall be used. The moment slab shall have a minimum length of 20 feet or per design. The width of the moment slab shall be determined by design. In all cases, the moment slab shall be sized to prevent overturning and sliding of the barrier system during impact. When the moment slab extends over the tops of the facing units to form a coping, a recess into which the facing units fit must be designed in the underside of the slab and a positive bond breaker must be provided to ensure isolation of the barrier from the facing units. Both vertical and horizontal bond breaks are required to avoid direct impact loads on the facing unit and to prevent prying loads on the top panels during traffic loading. If a precast coping or precast traffic barrier is used, the top of the wall must be smooth and free of steps or irregularities.

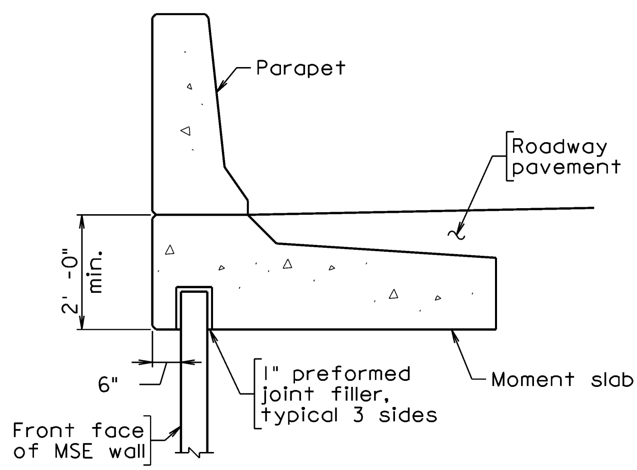


Isometric View

MSE Walls with Moment Slabs and Parapet (continued):



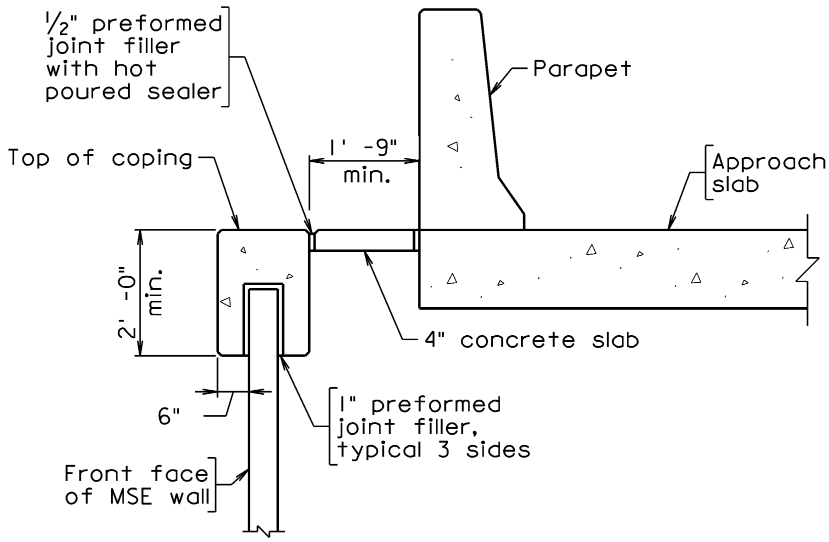
Section D – D Taken from File No. 18.05-6



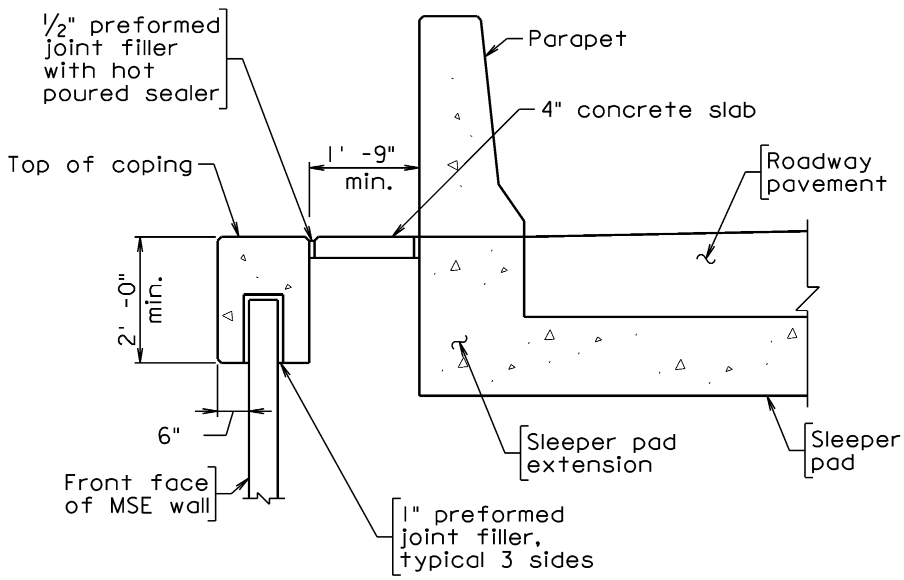
Section E – E Taken from File No. 18.05-6

MSE Walls with Approach Slabs and Parapet:

Where approach slab is used with MSE wall, the approach slab may be used as moment slab as shown in the following figures.



Section F – F Taken from File No. 18.05-6



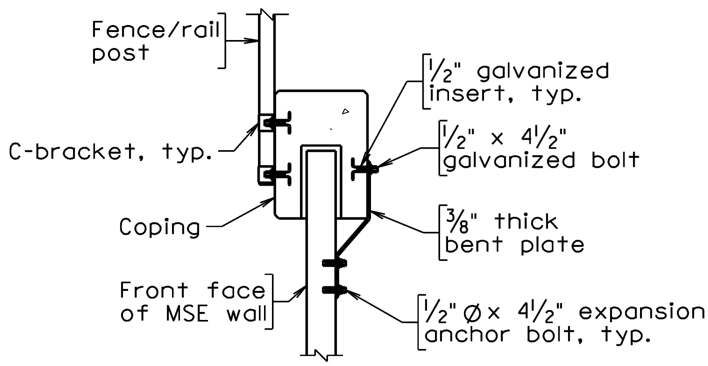
Section G – G Taken from File No. 18.05-6

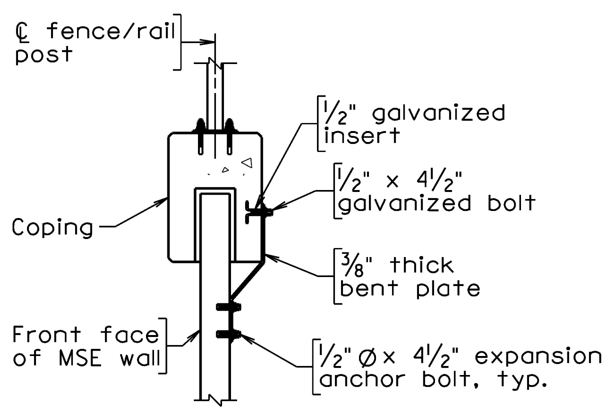
MSE Wall with Fencing and Handrail Details:

Where only pedestrian or bicycle loads are anticipated, the safety railing may be in the form of a concrete pedestrian parapet or fence/handrail.

A parapet may be located directly or nearly on top of the facing units. The parapet shall use a moment slab for stability. The moment slab may also serve as a sidewalk. The moment slab must be strong enough to resist the nominal (ultimate) strength of the pedestrian parapet. Where there is a possibility of vehicular load, the parapet and moment slab shall be designed for impact load.

Fence or handrails may be attached to the coping as shown in the following figures. Bent plates shall be used to secure the coping. Bent plates shall be designed but not less than 2 plates in ten feet in the horizontal direction.





(Other information not shown for clarity)

APPROVED RETAINING WALL SYSTEMS LIST

Category A Retaining Wall Systems will be allowed for most wall situations up to 40 feet in height.

Virginia Department of Transportation Approved List for Category A Retaining Wall Systems		
System	**Vendor**	**Limitations**
Reinforced Earth Walls	The Reinforced Earth Company 45610 Woodland Road, Suite 200 Sterling, VA 20166 (703) 547-8797 www.reinforcedearth.com	Requires approval by the VDOT Program Manager for Geotechnical Design of Structures for use on walls over 40 feet in height.
Retained Earth Walls	The Reinforced Earth Company 45610 Woodland Road, Suite 200 Sterling, VA 20166 (703) 547-8797 www.reinforcedearth.com	Requires approval by the VDOT Program Manager for Geotechnical Design of Structures for use on walls over 40 feet in height.
Reinforced Soil Embankment System	Hilfiker Retaining Walls 1902 Hilfiker Lane Eureka, CA 95503 (800) 762-8962 or (707) 443-5093 www.hilfiker.com	Requires approval by the VDOT Program Manager for Geotechnical Design of Structures for use on walls over 40 feet in height.
Vist-A-Wall Stabilized Earth Wall with Mesh Reinforcing	Big R Bridge - Vist-A-Wall Systems 19060 County Road, Greeley, CO 80631 (800) 234-0734 www.bigrbridge.com	Requires approval by the VDOT Program Manager for Geotechnical Design of Structures for use on walls over 40 feet in height.
Vist-A-Wall Stabilized Earth Wall with Grid-Strip Reinforcing	Big R Bridge - Vist-A-Wall Systems 19060 County Road, Greeley, CO 80631 (800) 234-0734 www.bigrbridge.com	Requires approval by the VDOT Program Manager for Geotechnical Design of Structures for use on walls over 40 feet in height.
Isogrid Walls	The Neel Company 8328-D Traford Lane Springfield, VA 22152 (703) 913-7858 www.neelco.com	Requires approval by the VDOT Program Manager for Geotechnical Design of Structures for use on walls over 40 feet in height.
T-Wall Retaining System	The Reinforced Earth Company 45610 Woodland Road, Suite 200 Sterling, VA 20166 (703) 547-8797 www.reinforcedearth.com	Requires approval by the VDOT Program Manager for Geotechnical Design of Structures for use on walls over 40 feet in height.
EarthTrac Reinforced Soil Wall System	Ground Improvement Systems, LLC 114 South Collins Street Arlington, TX 76034 (817) 223-0969 www.groundimprovementsystems.com	Requires approval by the VDOT Program Manager for Geotechnical Design of Structures for use on walls over 40 feet in height.

Virginia Department of Transportation Approved List for Category A Retaining Wall Systems (Continued)		
System	**Vendor**	**Limitations**
Sine Wall MSE Panel System	The Reinforced Earth Company 45610 Woodland Road, Suite 200 Sterling, VA 20166 (703) 547-8797 www.reinforcedearth.com	Requires approval by the VDOT Program Manager for Geotechnical Design of Structures for use on walls over 40 feet in height.
Tricon Retained Soil Wall	Tricon Precast, Ltd 15055 Henry Road Houston, TX 77060 (281) 931-9832 www.triconprecast.com	Requires approval by the VDOT Program Manager for Geotechnical Design of Structures for use on walls over 30 feet in height.
MSE Plus	SSL 4740-E Scotts Valley Drive Scotts Valley, CA 95066 (831) 430-9300 www.mseplus.com	Requires approval by the VDOT Program Manager for Geotechnical Design of Structures for use on walls over 30 feet in height.
Strengthened Earth Walls	Hanson Concrete Products 3500 Maple Avenue Dallas, TX 75219 (214) 525-5877	Requires approval by the VDOT Program Manager for Geotechnical Design of Structures for use on walls over 30 feet in height.
ARES Retaining Wall System	Tensar International Corporation 2500 Northwinds Parkway, Suite 500 Alpharetta, GA 30009 (888) 828-5126 www.tensarcorp.com	Requires approval by the VDOT Program Manager for Geotechnical Design of Structures for use on walls over 30 feet in height or for use on wrap around abutments.
MESA Retaining Wall System	Tensar International Corporation 2500 Northwinds Parkway, Suite 500 Alpharetta, GA 30009 (888) 828-5126 www.tensarcorp.com	Requires approval by the VDOT Program Manager for Geotechnical Design of Structures for use on walls over 30 feet in height or for use on wrap around abutments. Cannot be used within splash zones as defined in IIM-S&B-81.
MacRes Retaining Wall System	Maccaferri, Inc. 10303 Governor Lane Boulevard Williamsport, Maryland 21795 (301) 223-6910 www.maccaferri-usa.com	Requires approval by the VDOT Program Manager for Geotechnical Design of Structures for use on walls over 30 feet in height.
GeoMega™ MSE Wall System	The Reinforced Earth Company 45610 Woodland Road, Suite 200 Sterling, VA 20166 (703) 547-8797 www.reinforcedearth.com	Requires approval by the VDOT Program Manager for Geotechnical Design of Structures for use on walls over 30 feet in height.

Virginia Department of Transportation Approved List for Category A Retaining Wall Systems (Continued)		
System	**Vendor**	**Limitations**
Gravix DOT/Rail Precast Retaining Wall System	Smith-Midland 5119 Catlett Rd, Midland, VA 22728 (540) 439-3266 https://smithmidland.com	Requires approval by the VDOT Program Manager for Geotechnical Design of Structures for use on walls over 30 feet in height or for use on wrap around abutments.
KEYSYSTEM I Retaining Wall	Keystone Retaining Wall Systems, LLC. 4444 West 78th Street Minneapolis, MN 55435 (952) 897-1040 www.keystonewalls.com	Requires approval by the VDOT Program Manager for Geotechnical Design of Structures for use on walls over 30 feet in height or for use on wrap around abutments. Cannot be used within splash zones as defined in IIM-S&B-81.
LANDMARK Wall System with Mirafi's Miragrid Reinforcement	Eagle Bay 1231 Willis Road, Richmond, VA 23237 (800) 321-9141 www.eaglebayusa.com	Requires approval by the VDOT Program Manager for Geotechnical Design of Structures for use on walls over 30 feet in height or for use on wrap around abutments. Cannot be used within splash zones as defined in IIM-S&B-81.

Category B Retaining Wall Systems will be allowed for most wall situations up to 30 feet in height.

Virginia Department of Transportation Approved List for Category B Retaining Wall Systems		
System	**Vendor**	**Limitations**
Concrete Gravity Retaining Wall: RW-3	VDOT Road and Bridge Standards Volume I : 401.02	Maximum Height $\leq$ 15' Walls under 10' must be modified to add parapet to top of wall.
Standard Reinforced Concrete Crib Wall: CW-1	VDOT Road and Bridge Standards Volume I : 402.01	Maximum Height $\leq$ 23'-5" Live load surcharge shall not come within 10' of the top of wall.
EVERGREEN Retaining Wall	Permatile Concrete Products Co. P.O. Box 2049 100 Beacon Road Bristol, VA 24203 (540) 669-2120	Maximum Height $\leq$ 30' Live load surcharge shall not come within 10' of the top of wall.
Stone Strong Gravity Walls	Allied Concrete Company 1000 Harris Street Charlottesville, VA 22902 (434) 296-7181	Maximum Height $\leq$ 15' Live load surcharge shall not come within 10' of the top of wall.
ReCon Gravity Wall	Boxley Materials Company 15418 West Lynchburg Salem Turnpike Blue Ridge, VA 24064 (800) 422-2565 www.reconwalls.com	Maximum Height $\leq$ 15' Live load surcharge shall not come within 10' of the top of wall.

Category C Retaining Wall Systems will be allowed for most wall situations up to 30 feet in height that do not support railroads, highways, bridges or special loadings within the failure wedge producing active earth pressures. The failure wedge for this case will be assumed to extend a distance back from the face of wall of 1.3 times the wall height or 10 feet, whichever is greater.

Virginia Department of Transportation Approved List for Category C Retaining Wall Systems		
System	**Vendor**	**Limitations**
LOCK+LOAD™ Retaining Wall System	Mid-Atlantic LOCK+LOAD, LLC 11111 Industrial Road, Suite 201 Manassas, VA 20109 (703) 330-6535 http://www.lock-load.com	Requires approval by the VDOT Program Manager for Geotechnical Design of Structures for use on walls over 25 feet in height or non-critical walls with loads in the failure wedge.
Redi-Rock PC Retaining Wall System with Mirafi's Miragrid Reinforcement	Allied Concrete Company 1000 Harris Street Charlottesville, VA 22902 (434) 296-7181	Requires approval by the VDOT Program Manager for Geotechnical Design of Structures for use on walls over 25 feet in height or non-critical walls with loads in the failure wedge.
KEYSYSTEM II Retaining Wall with Mirafi's Miragrid Reinforcement	Keystone Retaining Wall Systems, LLC. 4444 West 78th Street Minneapolis, MN 55435 (952) 897-1040 www.keystonewalls.com	Requires approval by the VDOT Program Manager for Geotechnical Design of Structures for use on walls over 25 feet in height or non-critical walls with loads in the failure wedge. Cannot be used within splash zones as defined in IIM-S&B-81.
Anchor Vertica Wall System with Mirafi's Miragrid Reinforcement	Eagle Bay 1231 Willis Road, Richmond, VA 23237 (800) 321-9141 www.eaglebayusa.com	Requires approval by the VDOT Program Manager for Geotechnical Design of Structures for use on walls over 25 feet in height or non-critical walls with loads in the failure wedge. Cannot be used within splash zones as defined in IIM-S&B-81.
ReCon MSE Wall with Strata SG Geogrid Reinforcement	Boxley Materials Company 15418 West Lynchburg Salem Turnpike Blue Ridge, VA 24064 (800) 422-2565 www.reconwalls.com	Requires approval by the VDOT Program Manager for Geotechnical Design of Structures for use on walls over 25 feet in height or non-critical walls with loads in the failure wedge.

Category D Retaining Wall Systems will be allowed for most wall situations up to 20 feet in height that do not support railroads, highways, bridges or special loadings within the failure wedge producing active earth pressures. The failure wedge for this case will be assumed to extend a distance back from the face of wall of 1.3 times the wall height or 10 feet, whichever is greater.

Virginia Department of Transportation Approved List for Category D Retaining Wall Systems		
System	**Vendor**	**Limitations**
Concrete Gravity Retaining Wall: RW-2	VDOT Road and Bridge Standards Volume I : 401.01	Maximum Height $\leq$ 15' Wall may not carry surcharge loadings.

ALTERNATE RETAINING WALL SYSTEMS APPROVAL PROCESS

This document provides guidelines for proprietary retaining wall systems that are desire to be VDOT approved alternate retaining wall systems. All retaining walls constructed within VDOT right-of-way or maintained by VDOT must be on the Approved Retaining Wall Systems List.

For retaining wall system to be included in the Approved Retaining Wall Systems List, the system must go through a three-step approval process as outlined below:

Step 1: Request for Consideration

A wall system representative requests in writing to the Geotechnical Section of Structure and Bridge Division the desire to have the wall system placed on the list.

Structure and Bridge Division Geotechnical Section will base on the following factors to determine whether the wall system is acceptable for consideration.

(A) The system has a sound theoretical and practical basis for the engineers to evaluate its claimed performance.
(B) Past experience in construction and performance of the proposed system.

Step 2: Wall System Submittal

If the wall system is accepted for consideration, the wall system representative must submit a package which includes:

Option I: A system evaluation by the Highway Innovative Technology Evaluation Center (HITEC) as outlined in the Civil Engineering Research Foundation (CERF) requirements.

Option II:
(A) wall system history, including the year it was first used,
(B) wall system theory and how the theory was developed,
(C) laboratory and field experiments which support the theory,
(D) practical applications with descriptions, color photos, and/or videotape,
(E) details of wall elements, including facing unit, metallic/geosynthetics reinforcement, connection devices, backfill, leveling pad, bearing pad, filter fabric, drainage elements, coping, traffic barrier, etc.,
(F) analysis of structural elements, design calculations, factors of safety, estimated life,
(G) corrosion design procedure for metallic reinforcement, including procedures and data for field and laboratory evaluation,
(H) creep, durability, installation damage factors for geosynthetics reinforcement, including procedures and data for field and laboratory evaluation,
(I) detailed long hand design calculations for the design cases shown in Appendix A,
(J) limitations and disadvantages of the system,
(K) performance history, any known problems or failures of the system, including where, when, how and why it failed,
(L) list of users (other states, etc.) including contact names, addresses and phone numbers,
(M) sample material and construction control specifications--showing material type, quality, certifications, field testing, acceptance and rejection criteria (tolerances) and placement procedures,
(N) a well documented field construction manual describing in detail, and with illustrations where necessary, the step by step construction sequence, and any special equipment required,

(O) typical unit costs, supported by data from actual projects,
(P) quality control/quality assurance procedures for materials, wall system, and engineering,
(Q) information on wall system warranties and insurance coverage for responsible party.
(R) Independent Design Review: the wall company must have the total wall system reviewed by an independent professional engineer, registered in Virginia and acceptable to Structure and Bridge Division Geotechnical Section.

The independent professional engineer shall at no expense to VDOT, review all wall components, materials specifications, design concept, calculations, and construction procedures, for compliance with AASHTO, and VDOT criteria. If the independent professional engineer finds the wall system meets AASHTO and VDOT criteria and submits a formal evaluation report, the wall system will be added to the Approved Alternate Retaining Wall Systems List.

Wall system submitted under Option I and having at least 25,000 square feet of successful wall completion on Federal and/or State highway projects, after final review and approval by the VDOT Structure and Bridge Division Program Manager for the Geotechnical Design of Structures will be assigned to the appropriate wall category.

Wall system submitted under Option II and having at least 25,000 square feet of successful wall completion on Federal and/or State highway projects, after final review and approval by the VDOT Structure and Bridge Division Program Manager for the Geotechnical Design of Structures will be assigned to Category D. After the successful completion on at least 3 VDOT projects, totaling at least 10,000 square feet, the system will be re-evaluated for consideration on assignment to other category that may be applicable.

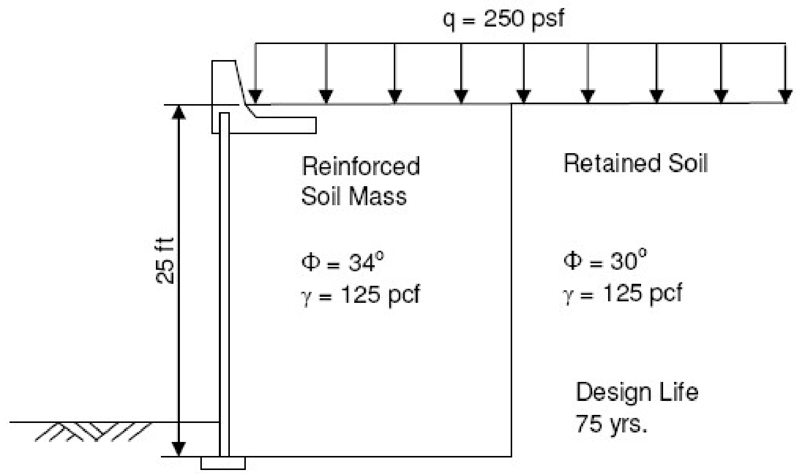
Step 3: Submittal of Standard Details

Once an alternate retaining wall system is approved, the wall company shall provide standard details and specifications showing facing unit, earth reinforcements, connection devices, leveling pad, coping, traffic barrier, etc. for review and approval. Once approved, these details will be kept on file. The wall company shall submit construction plans, etc. using only the approved details, specifications, etc. on file. Shop drawing review will be based on these details.

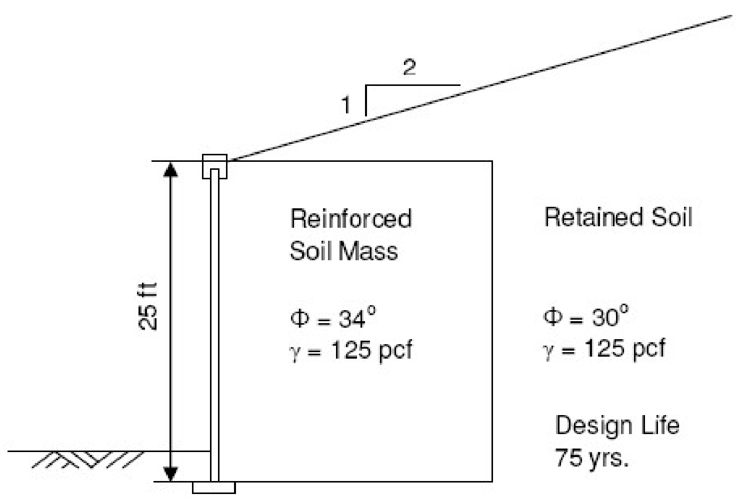
Revision to Approved Alternate Retaining Walls:
Should any detail, specification, etc. change, the wall company must submit the revision for review and approval, prior to using that revision on VDOT projects. Revision may not be submitted for projects which are already bid.

Example Design Problems:

Problem 1 (wall supporting traffic, without seismic) and Problem 2 (wall supporting traffic with seismic acceleration coefficient, A, of 0.15g).



Problem 3 (wall with a 2:1 infinite long backslope, without seismic) and Problem 4 (wall with a 2:1 infinite long backslope, with seismic acceleration coefficient, A, of 0.15g).



ADDITIONAL INFORMATION FOR RETAINING WALLS

CAST-IN-PLACE (CIP) CONCRETE GRAVITY WALL:

Category of Wall: Rigid Gravity Wall
Classification of Wall: Externally Stabilized Fill Wall

Description
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. Design procedures are well established for overturning and sliding analyses, and for evaluation of the bearing capacity of the underlying foundation soils. Backfill soil should be free draining to prevent water pressure from acting on the back of the wall. Standard details and requirements for gravity retaining walls (RW-2 and RW-3) can be found in *VDOT Road and Bridge Standards Volume 1 Section 400.*

General
Typical applications: Retaining walls
Size requirements: Base width ranges from 0.5 to 0.7 of the wall height.
Typical height range: 1 - 5 m

Advantages
- Conventional wall system with well-established design procedures and performance characteristics.
- Concrete is very durable in many environments.
- Concrete can be formed, textured, and colored to meet aesthetic requirements.
- Wall system is economical for wall heights less than 3 m.

Disadvantages
- Wall system requires a relatively long construction period because formwork must be erected and concrete must be poured and allowed to cure before backfill loads can be applied to the wall.
- Wall system cost will significantly increase if adequate source of select backfill is not available near project site.
- Wall system may not be economical for cut applications due to additional cost associated with constructing temporary excavation support to provide sufficient base width to construct the wall.
- Deep foundation support, which increases wall system cost and construction time significantly, may be required if wall is founded on weak or marginal soils.
- Wall system is rigid and is sensitive to total and different settlement.
- Wall system is typically not cost-effective for temporary applications.

Primary System Components
- Mass concrete, generally without steel reinforcement.
- Granular soil backfill.
- Drainage system(s).

Additional Comments
- Batching, placement, and curing times of concrete should be monitored.
- Foundations should be adequately compacted before concrete is placed.

CAST-IN-PLACE (CIP) CONCRETE CANTILEVER/COUNTERFORT WALL:

Category of Wall:	Semi-gravity Wall
Classification of Wall:	Externally Stabilized Fill Wall

Description

A CIP concrete cantilever wall consists of a steel-reinforced concrete wall stem and base slab connected to form the shape of an inverted "T". A CIP concrete counterfort wall is a cantilever wall which employs triangular braces at regular intervals along the length of the wall to provide additional lateral resistance. These walls rely on self-weight plus the weight of soil above the base slab to resist overturning and sliding due to lateral stresses of the retained soil behind the wall. Design procedures are well established for overturning and sliding analyses, and for evaluation of the bearing capacity of the underlying foundation soils. The structural design of a cantilever and counterfort wall assumes that the wall stem and the base slab are fixed at the junction between the two members and act as cantilever beams. Counterforts tie the wall stem and the base slab together and reduce bending moments and shears in the wall members through the transfer of tensile forces in the counterforts. Backfill soil should be free draining to prevent water pressure from acting on the back of the wall.

General

Typical applications:	Bridge abutments, retaining walls, slope stabilization
Size requirements:	Base width ranges from 0.4 to 0.7 of the wall height.
Typical height range:	2-9 m (cantilever wall); 9-18 m (counterfort wall)

Advantages

- Conventional wall system with well-established design procedures and performance characteristics.
- Concrete is very durable in many environments.
- Concrete can be formed, textured, and colored to meet aesthetic requirements.
- Counterfort walls undergo less lateral displacement than cantilever walls.

Disadvantages

- Wall system requires a relatively long construction period because formwork must be erected and concrete must be poured and allowed to cure before backfill loads can be applied to the wall.
- Wall system cost will significantly increase if adequate source of select backfill is not available near project site.
- Wall system may not be economical for cut applications due to additional cost associated with constructing temporary excavation support to provide sufficient base width to construct the wall.
- Deep foundation support, which increases wall system cost and construction time significantly, may be required if wall is founded on weak or marginal soils.
- Wall system is rigid and is sensitive to total and different settlement.
- Since counterfort walls typically deflect less than cantilever walls, it may be necessary to design these walls to resist higher earth pressures.
- Wall system is typically not cost-effective for temporary applications.

Primary System Components

- Reinforced concrete.
- Granular soil backfill.
- Drainage system(s).

Additional Comments

- Batching, placement, and curing times of concrete should be monitored.
- Foundations should be adequately compacted before concrete is placed.
- Wall stems which are less than 3 m in height are typically constructed with constant cross-sectional thickness.
- Resistance to sliding can be increased by constructing a key into the underlying foundation.
- Counterfort walls are used for situations in which unusually high pressures are expected to act on the back of the wall or for wall heights generally greater than 9 m.
- L-shaped cantilever wall may be necessary in areas with strict right-of-way requirements.

CRIB WALL:

Category of Wall: Prefabricated Modular Gravity Wall
Classification of Wall: Externally Stabilized Fill Wall

Description

A concrete crib wall is a gravity retaining structure constructed of interlocking prefabricated reinforced or unreinforced concrete elements. Timber crib walls can be constructed or either stacked “log-cabin style” prefabricated timber elements or stacked timber beams that are nailed together using steel spikes. Each crib is compromised of alternating transverse and longitudinal horizontal beams. Each crib unit is filled with granular, free draining soil, which is compacted inside each unit. Design of a crib wall for global stability is similar to that of a CIP concrete gravity wall. The weight of a soil-filled crib unit resists overturning and sliding due to the lateral stresses of the retained soil behind the wall. Backfill soil should be free draining to prevent water pressure from acting on the back of the wall. Standard details and requirements for concrete crib walls can be found in *VDOT Road and Bridge Standards Volume 1 Section 400.*

General

Typical applications: Retaining walls, slope stabilization
Size requirements: Base width ranges from 0.5 to 0.7 of the wall height.
Typical height range: 2-11 m
Commercially-
available system: Criblock ® (concrete); Permacrib ® (timber)

Advantages

- Construction is rapid and does not require specialized labor or equipment.
- Wall elements are relatively small in size.
- Wall system construction does not require heavy equipment.

Disadvantages

- Wall system may not be economical for cut applications due to additional cost associated with constructing temporary excavation support to provide sufficient base width to construct the wall.
- On-site design changes are difficult since components are prefabricated off-site.
- Limited space within bins makes use of hand compaction equipment necessary.
- Standard components may require modification for use in wall systems with significant horizontal curvature.
- Wall system can only accommodate minor differential settlements.
- Wall system is typically not cost-effective for temporary applications.

Primary System Components

- Prefabricated concrete or timber elements.
- Granular soil backfill (inside crib units and behind wall).
- Drainage system(s).

Additional Comments

- Proper compaction of fill in the crib units is necessary to minimize wall settlement and distortion.
- At a given level, the fill inside the crib units should be placed and compacted prior to backfilling behind the wall.
- Walls can be constructed with batters.
- Open-faced crib walls require coarsely graded backfill or filter protection such as a geotextile to prevent flow of soil through openings in the face of the wall.

SEGMENTAL PRECAST FACING MECHANICALLY STABILIZED EARTH (MSE) WALL:

Category of Wall: Mechanically Stabilized Earth (MSE) Wall
Classification of Wall: Internally Stabilized Fill Wall

Description

A segmental, precast facing mechanically stabilized earth (MSE) wall employs metallic (strip or bar mat) or geosynthetic (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 or one or more compacted lifts. A free draining, non-plastic backfill soil is required to ensure adequate performance or the wall system. For walls reinforced with metallic strips, load is transferred from the backfill soil to the strip reinforcement by shear along the interface. For walls with ribbed strips, bar mats, or grid reinforcement, load is similarly transferred but an additional component of strength is obtained through the passive resistance on the transverse members of the reinforcement. Metallic reinforcement and high modulus geosynthetic reinforcement, which are relatively inextensible, require less deformation to mobilize shear strength as compared to geotextiles and lower and modulus geogrids. Facing panels are typically square, rectangular, hexagonal, or cruciform in shape and are up to 4.5 m^2 in area.

General

Typical applications:	Bridge abutments, retaining walls, slope stabilization
Special applications:	Seawalls, dams, storage bunkers
Size requirements:	Typical minimum reinforcement length is 0.7 of the wall height.
Typical height range:	3-20 m
Commercially-available systems:	See Approved Retaining Wall System List

Advantages

- Wall system construction is relatively rapid and does not require specialized labor or equipment.
- Limited foundation preparation is required.
- Wall system is flexible and can accommodate relatively large total and differential settlements without distress
- Reinforcement is light and easy to handle.
- Concrete facing panels permit greater flexibility in the choice of facing and architectural finishes.
- Since wall system is flexible, it is well-suited for applications in regions of high seismicity.

Disadvantages

- Wall system may not be economical for cut applications due to additional cost associated with constructing temporary excavation support to provide sufficient base width to construct the wall.
- Wall system requires relatively large base width.
- Use of metallic reinforcement requires that backfill meet minimum electrochemical requirements for corrosion protection.
- Allowable load for geosynthetic reinforcement must be reduced to account for creep, durability, and construction damage.
- Wall system may not be appropriate for applications: (1) where it may be necessary to gain future access to underground utilities; (2) at locations subject to scour; or (3) involving significant horizontal curvature.
- Wall system is typically not cost-effective for temporary applications.

Primary System Components

- Facing panels.
- Reinforcement (steel strip, steel bar mat, geosynthetics)
- Concrete leveling pad.
- Granular soil backfill.
- Drainage system(s).

Additional Comments

- Position and alignment of facing must be monitored to ensure proper fit and appearance.
- Design of metallic reinforcement requires provisions for loss of section thickness due to corrosion over design life.

PREFABRICATED MODULAR BLOCK FACING MECHANICALLY STABILIZED EARTH (MSE) WALL:

Category of Wall:	Mechanically Stabilized Earth (MSE) Wall
Classification of Wall:	Internally Stabilized Fill Wall

Description

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 backfill consists of one or more compacted lifts. The reinforcement may be connected to the wall face through fiction 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. A free draining, non-plastic backfill soil is required to ensure adequate performance of the wall system. Load is transferred from soil to the reinforcement through passive resistance on transverse member of the grid and interface friction between the soil and the surface of the reinforcement.

General

Typical applications:	Retaining walls, slope stabilization
Size requirements:	Typical minimum reinforcement length is 0.7 of the wall height.
Typical height range:	2-10 m
Commercially-available systems:	See Approved Retaining Wall System List

Advantages

- Wall system construction is relatively rapid and does not require specialized labor or equipment.
- Limited foundation preparation is required.
- Wall system is flexible and can accommodate relatively large total and differential settlements without distress
- Modular blocks are relatively light and easily handled.
- Reinforcement is relatively lightweight and easy to handle.
- Modular blocks permit flexibility in the choice of sizes, shapes, weights, textures, colors.
- Wall system can adapt to fairly sharp curves and significant front batter.

Disadvantages

- Wall system may not be economical for cut applications due to additional cost associated with constructing temporary excavation support to provide sufficient base width to construct the wall.
- Use of metallic reinforcement requires that backfill meet minimum electrochemical requirements for corrosion protection.
- Allowable load for geosynthetic reinforcement must be reduced to account for creep, durability, and construction damage.
- Wall system may not be appropriate for applications where it may be necessary to gain future access to underground utilities or where scour is anticipated.
- Geosynthetic reinforcement may be damaged by oversize backfill or excessive compaction.
- Wall system is typically not cost-effective for temporary applications.

Primary System Components

- Modular concrete blocks.
- Reinforcement (geogrid, metallic grid, geotextile)
- Leveling pad (concrete or crushed stone)
- Granular soil backfill.
- Drainage system(s).

Additional Comments

- Position and alignment of modular concrete blocks must be monitored to ensure proper fit and performance.
- Front batter is usually required to stack modular concrete blocks.
- Freeze-thaw durability of modular blocks may be improved by applying a sealant to the wall face following construction.

SHEET-PILE WALL:

Category of Wall: Non-gravity Cantilevered Wall
Classification of Wall: Externally Stabilized Cut Wall

Description
A sheet-pile wall consists of driven, vibrated, or pushed, interlocking steel or concrete sheet-pile 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.

General
Typical applications: Retaining walls, slope stabilization, excavation support
Special applications: Marine walls, docks
Size requirements: N/A
Typical height range: 2-5 m

Advantages
- Conventional wall system with well-established design procedures and performance characteristics.
- Wall system can be used for applications in which the wall penetrates below the ground-water table.
- Work area inside wall face is not required.
- Wall system is suitable for temporary applications.

Disadvantages

- Construction of wall system requires specialized equipment.
- Driving sheet-pile is noisy and it can induce vibrations which may be detrimental to nearby structures.
- Sheet-pile interlocks may be lost during driving which will allow water (for walls constructed in areas of high ground water) to advance into the excavation.
- Difficult to drive sheeting in hard or dense soils; also difficult to drive in gravelly soils.
- Wall height is limited based on required structural section.
- Wall system may undergo relatively large lateral movements which may be detrimental to nearby structures.

Primary System Components
- Steel or concrete sheet-pile.

Additional Comments
- Proper selection of pile hammer and cushioning is necessary to avoid tearing of pile interlock and excessive damage at the top of the sheet-pile.
- Wall system is typically used in potentially squeezing or running soils such as soft clays and cohesionless silt or loose sand below the water table.
- Approximate penetration depths for cantilevered sheet-pile walls at different soil densities are shown in Table 3.

TABLE 3 APPROXIMATE PENETRATION DEPTHS FOR CANTILEVERED SHEET-PILE WALLS (AFTER NAVFAC, 1986)

SPT (N) blows/foot	Relative Density	Depth of Embedment
0 - 4	very loose	2.0H (1)
5 – 10	loose	1.5H
11 – 30	Medium dense	1.25H
31 – 50	Dense	1.0H
>50	Very dense	0.75H

Notes: (1) H is the height of the wall above final excavation grade

SOLDIER PILE AND LAGGING WALL:

Category of Wall: Non-gravity Cantilevered Wall
Classification of Wall: Externally Stabilized Cut Wall

Description
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. The spacing of the lagging varies from 2 to 3 m with a common spacing of 2.4 m. A portion of the load from the retained soil is transferred to the vertical elements through arching; (i.e., load is redistributed away from the lagging to the much stiffer soldier piles). The purpose of the lagging is to prevent the retained soil from eroding, which would destroy the arching effect. Soldier pile and lagging walls can be constructed with anchors.

General
Typical applications: Slope stabilization, temporary excavation support, retaining walls
Size requirements: N/A
Typical height range: 2-5 m

Advantages
- Conventional wall system with well-established design procedures and performance characteristics.
- Less soldier piles are driven than for the construction of a sheet-pile wall.
- Soldier piles can be drilled or driven.
- Wall system requires minimal work area inside wall face.
- Wall system is suitable for temporary applications.

Disadvantages
- Construction of wall system requires skilled labor and specialized equipment.
- Driving piles is noisy and it can induce vibrations that may be detrimental to nearby structures.
- Difficult to drive piles in hard or dense soils; also difficult to drive in soils with large cobbles and boulders.
- Pre-drilling of soldier piles, if required, is a significant cost component.
- Vibration may induce settlement in loose ground.
- Wall height is limited based on required structural system.
- Wall system may undergo relatively large lateral movements which may be detrimental to nearby structures.

Primary System Components
- Soldier piles (vertical wall elements)
- Lagging
- Facing panels (if required)
- Drainage system(s).

Additional Comments

- Construction of wall system in hard clays, shales, or cemented materials enables temporary lagging to be widely spaced or omitted provided soldier piles are sufficiently close.
- Wall system is highly pervious.
- Wall stiffness can be controlled by increasing or decreasing number of soldier piles.
- Wall system develops passive resistance only at the soldier pile locations.

ANCHORED WALL:

Category of Wall: Non-gravity Cantilevered Wall
Classification of Wall: Externally Stabilized Cut Wall

Description

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 designated 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 1 m 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.

General

Typical applications:	Bridge abutments, retaining walls, slope stabilization, excavation support
Size requirements:	Unbonded anchor length is typically 0.6 of wall height; actual length depends on minimum specified total anchor length and distance to a bearing strata
Typical height range:	5-20 m

Advantages

- Design procedures for anchors are well-established.
- Unlike internally braced excavations, an unobstructed working space can be achieved on the excavation side of the wall for an anchored wall.
- Relatively large horizontal earth pressures can be resisted by an anchored wall.
- Quality assurance is achieved through proof testing of each anchor.
- Wall system is suitable for temporary applications.

Disadvantages

- Construction of wall system requires skilled labor and specialized equipment.
- Underground easement may be required for anchors and anchor zone.
- Anchors may be difficult to construct where underground structures or utilities exist.
- Anchor capacity may be difficult to develop in some cohesive soils.

Primary System Components

- Soldier piles
- Lagging
- Facing panels (if required)
- Drainage system(s)
- Anchors

Additional Comments

- Corrosion protection of anchors is based on aggressiveness of soil and proposed design life (i.e., temporary or permanent of wall system).
- Lateral movements associated with excavation can be minimized through prestressing of the anchors.
- Boring must be made behind wall face to identify materials in anchor bond zone.

SOIL-NAILED WALL:

Category of Wall: In-situ Reinforced Wall
Classification of Wall: Internally Stabilized Cut Wall

Description

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., 1.0 to 2.0 m) 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 precast or CIP concrete facing panels may be installed after the wall is complete.

General

Typical applications:	Retaining walls, slope stabilization, excavation support, widening under existing bridge.
Special applications:	Tunnel facing support.
Size requirements:	Soil nail length ranges from 0.6 to 1.0 of the wall height; actual length depends on nail spacing and competency of in-situ soils.
Typical height range:	3-20 m

Advantages

- An unobstructed working space can be achieved on the excavation side of the wall.
- Surface movements can be limited by installing additional nails or by stressing nails in upper level to small percentage of working loads.
- Wall system is adaptable to varying site conditions.
- Wall system is well-suited for construction in areas of limited headroom.
- Wall embedment is not required as with other cut wall systems.
- Wall system is suitable for temporary applications.

Disadvantages

- Construction of wall system requires experience contractor.
- Underground easements for nails may be necessary.
- Construction of wall system below ground water requires that slope face to permanently dewatered.
- Closely spaced nails may interface with underground utilities.
- Nail capacity may be difficult to develop in some cohesive soils.

Primary System Components

- Shotcrete
- Permanent facing (if required)
- Drainage system(s)
- Soil nails

Additional Comments

- Initial depths of excavation should be decreased if wall face cannot be supported prior to shotcreting.
- Continuity in vertical drains from level to level must be ensured.
- Wall system performance relies on rapid placement of nails and shotcrete after each stage of excavation.
- Nails must be designed with appropriate corrosion protection schemes.

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