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EARTH RETAINING SYSTEM CLASSIFICATION

The purpose of an earth retaining system is to stabilize an otherwise unstable soil mass by means of lateral support or reinforcement. 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 are, however, 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.

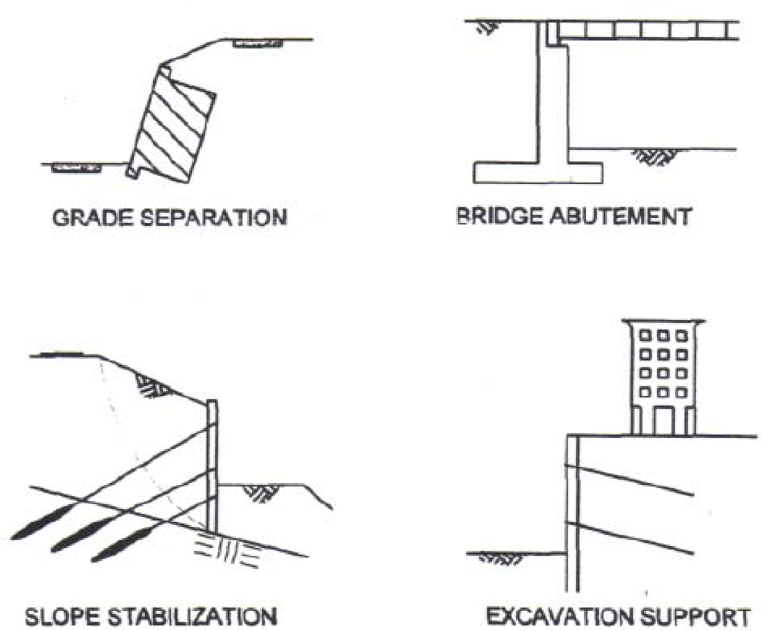


FIGURE 1 APPLICATIONS OF EARTH RETAINING SYSTEMS

A classification system for earth retaining systems is presented in Figure 2. In Figure 2, earth retaining systems 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). Fill wall construction refers to a wall system in which the wall is constructed from the base of the wall to the top (i.e., “bottom-up” construction). Cut wall construction refers to a wall system in which the wall is constructed from the top of the wall to the base (i.e., “top-down” construction). 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. Externally stabilized wall systems utilize an external structural wall, against which stabilizing forces are mobilized. Internally stabilized wall systems employ reinforcement which extends within and beyond the potential failure mass. Using Figure 2, 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

FIGURE 2 EARTH RETAINING SYSTEM CLASSIFICATION

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	Required ROW[1]	Differential Settlement Tolerance[2]
Concrete gravity wall	√		1 – 3m	0.5 – 0.7 H[3]	1/500
Concrete cantilever wall	√		2 – 9 m	0.4 – 0.7 H[3]	1/500
Concrete counterforted wall	√		9 – 18m	0.4 – 0.7 H[3]	1/500
Concrete crib wall	√		2 – 11m	0.5 - 0.7 H	1/300
Metal bin wall	√		2 – 11m	0.5 – 0.7 H	1/300
Gabion wall	√		2 -8m	0.5 – 0.7 H	1/50
MSE wall (precast facing)	√		3 – 20 m	0.7 – 1.0 H	1/100
MSE wall (modulus block facing)	√		2 – 7m	0.7 – 1.0 H	1/200
MSE wall (geotextile/geogrid/welded wire facing)	√	√	2 - 15 m	0.7 – 1.0 H	1/60
Reinforced Soil Slopes (RSS)	√	√	3 -30 m	0.5 – 1.0 H	1/60

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) Ratio of the difference in vertical settlement between two points along the wall to the horizontal distance between the points.
(3) ROW requirement given is the typical wall base width as a fraction of wall height, H.

TABLE 1 SYSTEM SELECTION CHART FOR FILL WALLS (CONT)

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
Metal bin wall	Does not require skill labor or specialized equipment Rapid construction	Difficult to make height adjustments in field Subject to corrosion in aggressive environment
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)	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	Required ROW[3]	Lateral Movement	Water Tightness
Sheet-pile wall	√	√	Up to 5 m	None	Large	Fair
Solider pile/lagging wall	√	√	Up to 5 m	None	Medium	Poor
Slurry (diaphragm) wall	√	√	6 – 24 m[1]	None [4]	Small	Good
Tangent pile wall	√	√	3 – 9 m 6 – 24 m [1]	None [4]	Small	Fair
Secant pile wall	√	√	3 – 9 m 6 – 24 m [1]	None [4]	Small	Fair
Soil mixed wall	√	√	6 – 24 m [1]	None [4]	Small	Fair
Anchored wall	√	√	5 – 20 m [2]	0.6H + anchor bond length	Small - medium	N/A
Soil nailed wall	√	√	3 – 20 m	0.6 – 1.0 H	Small - medium	N/A
Micropile wall	√		N/A	Varies	N/A	N/A

Notes:
(1) Height range given is for wall with anchors.
(2) For solider pile and lagging wall only.
(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)

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

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.

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. Instead, discussions of major design topics for fill and cut walls are presented herein. The reader is directed to appropriate references for detailed design and analysis procedures.

A general design methodology that is valid for both fill and cut walls is outlined in Table 4. 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 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) includes evaluating geotechnical properties necessary for wall design; Step (3) involves wall system selection; Steps (4) through (11) address specific geotechnical and structural design requirements. Step (12) involves contracting approach and documents preparation.

TABLE 4 TYPICAL DESIGN STEPS FOR EARTH RETAINING SYSTEMS

(1)	Establish project requirements including wall geometry, external loadings, performance criteria, and construction constraints.
(2)	Evaluate site subsurface conditions and properties of in-situ soil and rock.
(3)	Select wall system.
(4)	Select wall construction materials. Evaluate design properties.
(5)	Establish design factors of safety.
(6)	Determine preliminary wall dimensions.
(7)	Evaluate lateral earth pressures on back of wall.
(8)	Check external stability and revise dimensions if necessary.
(9)	Check internal stability and revise dimensions if necessary.
(10)	Estimate vertical and differential settlement and lateral wall movements. Revise dimensions if necessary.
(11)	Design auxiliary components such as drainage systems and facing systems.
(12)	Identify contracting approach and prepare appropriate contract documents.

EARTH RETAINING SYSTEM DESIGN

The purpose of this section is to present and discuss several design concepts relevant to fill and cut wall systems. Topics discussed herein for fill and cut walls are listed below:

- Fill walls
    - external stability
    - backfill soil
    - wall foundations
    - internal stability and structural design
- Cut walls
    - earth pressure diagrams
    - corrosion protection of anchors and soil nails
    - internal stability and structural design

Fill Walls

External Stability

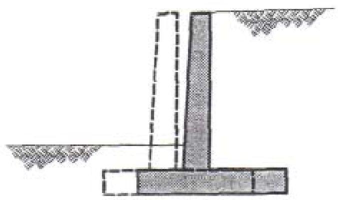
External stability analyses are used in design to evaluate the ability of the wall to resist lateral pressures applied by surcharges and the backfill and retained soil. The possible modes of external instability that are generally considered are illustrated in Figure 3. Although Figure 3 shows a cantilever wall, these modes of external instability are typically considered for all types of fill walls. Figure 4 shows the external forces that act on a typical wall system. A wall must be proportioned to ensure an adequate factor of safety (FS) against failure as described below.

Sliding

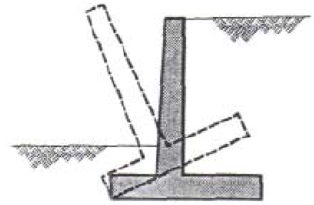
Sliding may occur when the lateral pressure on the wall exceeds the available lateral resistance along the base of the wall. The lateral resistance may have several components including frictional resistance and adhesion that can be mobilized between the base of the wall and the underlying wall foundation soil or rock and passive resistance from the soil in front of the wall or adjacent to any foundation keyways. Passive resistance from soil in front of the wall is typically neglected for sliding stability calculations. For the case shown in Figure 4, the factor of safety, FS, against sliding would be given as:

$$FS = \frac{F_r}{P_h} = \frac{N\tan\delta_B + C_B B}{P_h} \qquad (1)$$

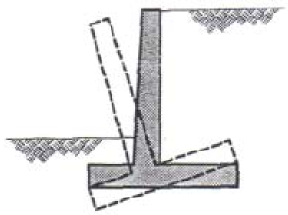
where N is the resultant vertical load, $ð_B$ is the interface friction angle between the wall base and the foundation, C_B is the adhesion between the wall base and the foundation, B is the wall base width, and P_h is the horizontal earth pressure resultant. Standard SI units are: N (kN/m); $ð_B$ (degrees); C_B (kPa); B (m); and P_h (kN/m). The minimum factor of safety against sliding is typically taken as 1.5 (AASHTO, 1994).



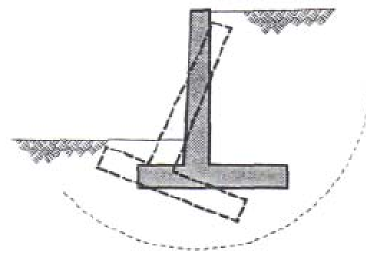
(a) SLIDING FAILURE



(b) OVERTURNING FAILURE

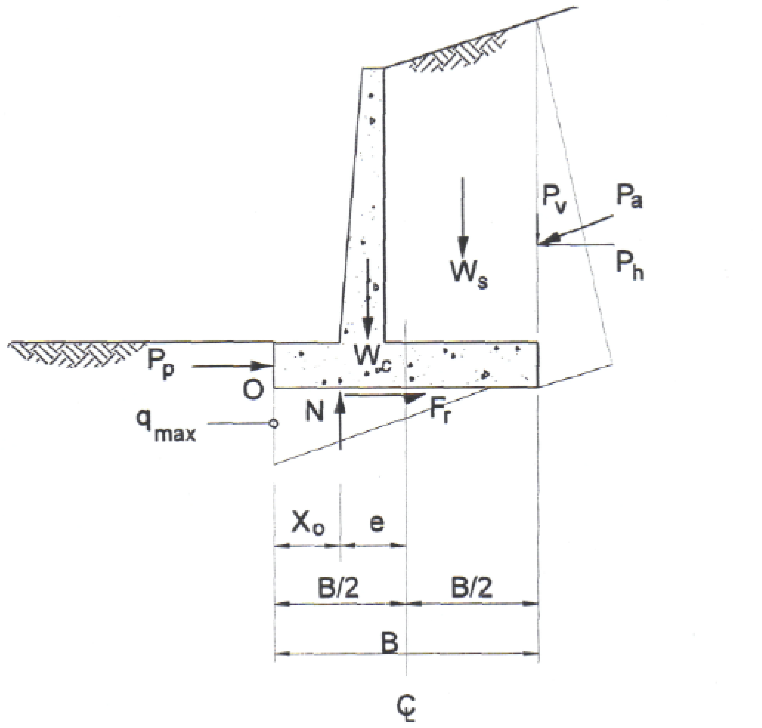


(c) BEARING CAPACITY



(d) DEEP-SEATED SLIDING FAILURE

If an adequate factor of safety against sliding cannot be achieved, design modifications should be considered. Modifications may include: (1) increasing the width of the wall base; (2) using an inclined wall base or battering the wall to decrease the horizontal load; (3) constructing a shear key; and (4) embedding the wall foundation or slope base to a depth for which adequate lateral resistance can be mobilized. Other types of modifications include lengthening the reinforcement for MSE walls and RSS, using denser stone for gabion walls, and constructing a berm at the toe of a reinforced soil slope to act as a buttress.



NOTATIONS:

P_p = passive earth pressure resultant (kN/m)
P_a = active earth pressure resultant (kN/m)
W_s = weight of soil above heel (kN/m)
W_c = weight of wall (kN/m)
N = vertical resultant force (kN/m)
F_r = N tan ð$_B$ + C_BB (kN/m)

FIGURE 4 FORCES ON AN EARTH RETAINING SYSTEM

Overturning

Overturning may occur when the driving moments (generated by the lateral pressure against the wall) are in excess of the resisting moments (generated by the self-weight of the wall and wall/soil interface friction). The factor of safety against overturning is calculated by summing moments about the toe of the wall (point O, Figure 4).

$$FS = \frac{\sum \text{Resisting Moment}}{\sum \text{Driving Moment}} \qquad (2)$$

The minimum factor of safety against overturning is typically taken as 2.0 for walls founded on soil and 1.5 for walls founded on rock (AASHTO, 1994). The overturning criterion is not considered applicable for the design analysis of MSE walls since these systems are relatively flexible and thus the potential for failure resulting from overturning is minimal. Overturning conditions can be improved by increasing the width of the wall or, for concrete cantilever walls, relocating the wall stem towards the heel of the wall base.

In addition, for walls founded on soil, the line of action of the resultant vertical load, N, must be within the middle third of the wall base. This condition can be expressed as:

$$e \le \frac{B}{6} \tag{3}$$

where the eccentricity, e, is the distance from the centerline of the wall to the line of action of the resultant vertical force and B is the width of the base of the wall (Figure 4). Standard SI units are: e (m); and B (m). The load eccentricity is caused by the moment applied to the wall foundation resulting from the horizontal component of earth pressure. This moment induces a non-uniform pressure on the bottom of the wall foundation and, if the eccentricity is greater than B/6, can lead to loss of contact pressure between the bottom of the wall and the ground. For walls founded on rock, the allowable eccentricity must be less than B/4 (AASHTO, 1994).

Bearing Capacity

Bearing capacity failure may occur when the maximum bearing pressure along the wall base (q_{max}) exceeds the allowable bearing pressure of the wall foundation soil or rock (q_u). The factor of safety against a bearing capacity failure can be expressed as:

$$FS = \frac{q_u}{q_{max}} \tag{4}$$

The value of q_{max} can be evaluated based on the magnitude and line of action of the resultant vertical load, N (NCHRP, 1991). The value of q_u can be established using bearing capacity theory. Standard SI units are: q_{max} (kPa); and q_u (kPa). The minimum factor of safety for bearing capacity failure is typically taken as 2.0 to 3.0 (AASHTO, 1994) depending on wall type and foundation material.

Bearing capacity can be improved by one or more of the following methods: (1) ground improvement; (2) increasing wall or slope embedment; (3) excavating weak soils and replacing with compacted fill; (4) employing staged construction techniques, and (5) increasing wall width.

Global Stability

Global instability may occur if the shear stresses along a deep-seated surface under the wall exceed the soil shear strength along the same surface. Both circular and non-circular surfaces should be considered. Commercially available slope stability computer programs employ limit equilibrium analysis methods and can be used to analyze global stability. Global stability can be improved by methods similar to those used for improving bearing capacity.

REFERENCES:

1. FHWA-SA-96-038 *GEOTECHNICAL ENGINEERING CIRCULAR NO. 2 - Earth Retaining Systems*, Federal Highway Administration, Washington, D.C., 1997.

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.

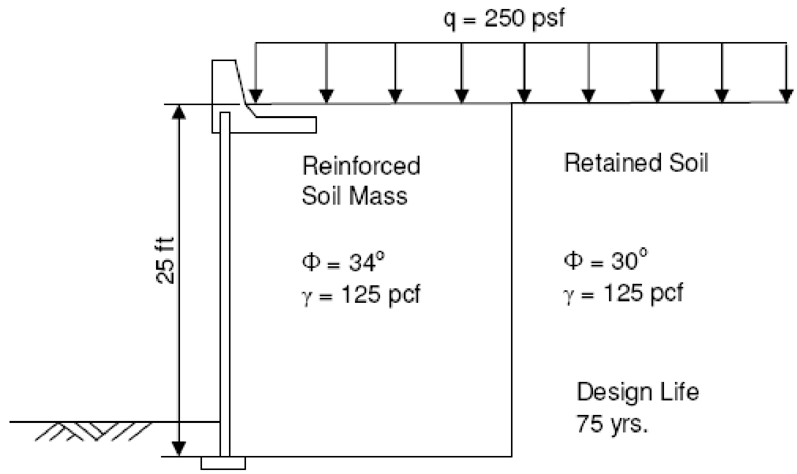
Step 3: Submittal of Standard Details

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.

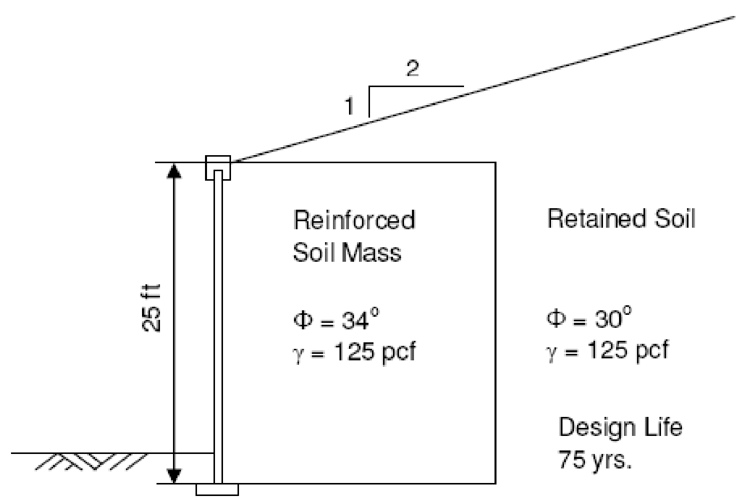
Revision to Approved Alternate Retaining Walls:
Should any detail, specification, etc change, the wall company must submit the revision for review and approval, prior to using that revision on VDOT projects. Revision may not be submitted for projects which are already bid.

Appendix A – 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)



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	**Vender**	**Limitations**
Reinforced Earth Walls	The Reinforced Earth Company 12001 Sunrise Valley Drive, Suite 400 Reston, VA 20191 (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 12001 Sunrise Valley Drive, Suite 400 Reston, VA 20191 (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 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 30 feet in height. Cannot be used for wrap around abutments.
EarthTrac HA MSE	EarthTec, Inc. 413 Browning Court Purceville, VA 20132 (703) 771-7305 www.earthteccorp.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 (Continue)		
System	**Vender**	**Limitations**
Sine Wall MSE Panel System	Sine Wall, LLC 11640 North Park Drive, Suite 110 Wake Forest, NC 27587 (919) 453-2011 www.sinewall.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.
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.
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.

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	**Vender**	**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	**Vender**	**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.
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.
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	**Vender**	**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.

GUIDELINES FOR PREPARATION OF ALTERNATE RETAINING 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 (geology sheets), laboratory test data, etc.] and estimate the location of the proposed bearing stratum.

3. Perform bearing capacity calculations to determine the maximum allowable soil bearing capacity at the estimated bearing stratum. ***The maximum allowable soil bearing pressure 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 bearing pressure that the wall will impose on the soil. If the maximum bearing pressure imposed by the wall is less than the maximum allowable soil bearing capacity calculated in Step 3, the bearing pressure 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 according to AASHTO.

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

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.

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.

A SETTLEMENT versus TIME curve shall be developed and used in tracking actual field measured settlements (See Attachment A for example).

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

7. Calculate factors of safety with respect to overturning, sliding, and global stability for the applicable loading conditions. If the factors of safety are greater than required, the 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 pressure, settlement, overturning, sliding and global stability requirements) are satisfied, alternate 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 alternate 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 global 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 capacity, settlement, and the factors of safety with respect to overturning, sliding, and global 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 the locations of all pipes and utilities that will be penetrating the wall or behind the panels, so the selected alternate wall company can design for those conditions.

14. Draw the Plan View. Show stationing, offsets, boring locations, and all pipes and utilities in the vicinity of the wall.

15. If required, rustication 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 capacity or global 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 overexcavation 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.

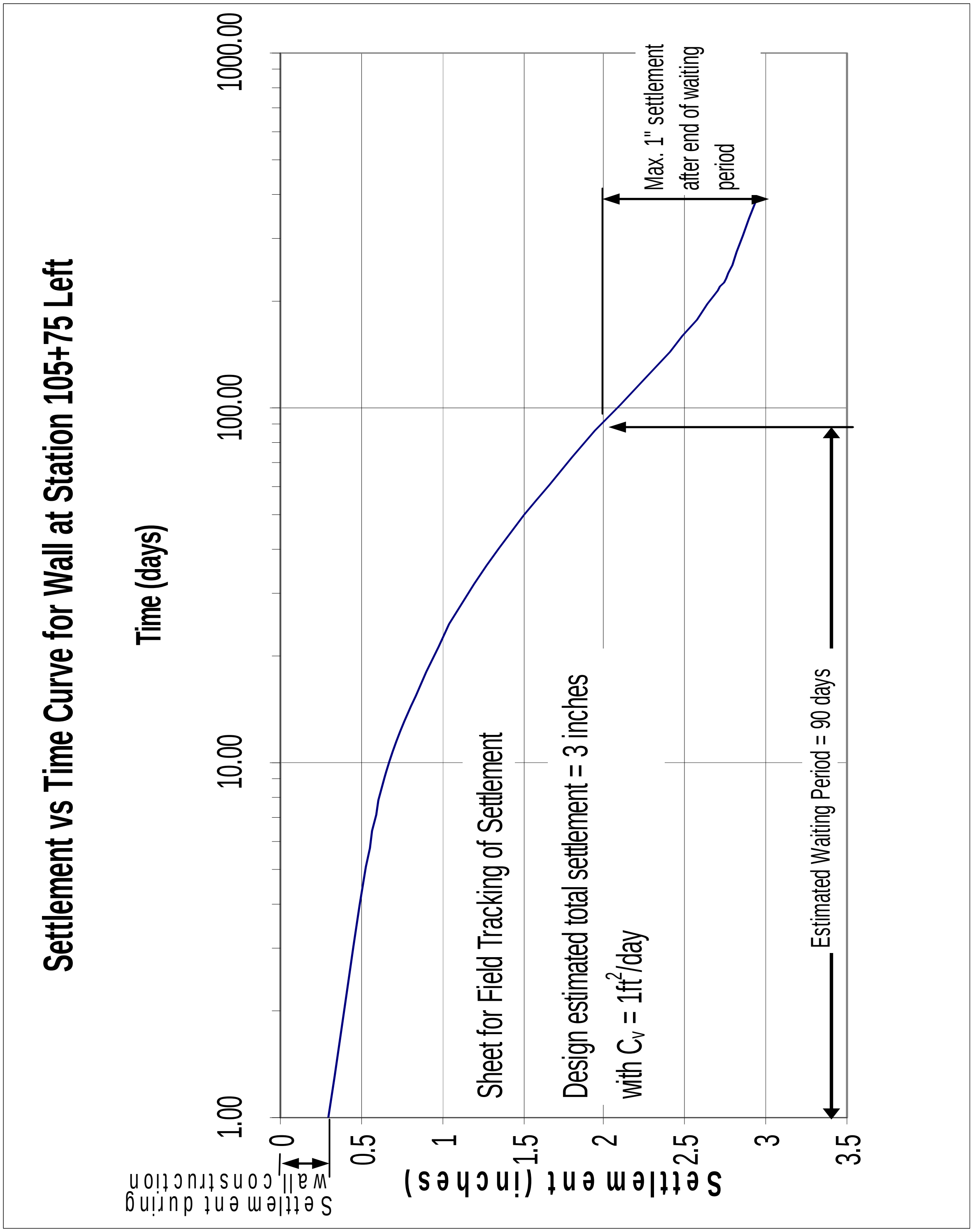
20. List the approved wall companies with their addresses and telephone numbers on the plans so the Contractor can contact them to request bids. Some projects have geometric constraints (e.g., walls that wrap around bridge abutments) that preclude the use of some wall systems. Wall systems that cannot 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 General Notes on the Plans.

ATTACHMENT A

Example of SETTLEMENT versus TIME Curves



GENERAL NOTES FOR ALTERNATE RETAINING 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 GENERAL NOTE on the Alternate Retaining Wall Plan.

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.

Specifications:

Construction: Virginia Department of Transportation Road and Bridge Specifications, 2007.

Design: AASHTO Standard Specifications for Highway Bridges, 16th Edition, 1996; 1997 and 1998 Interim Specifications; and VDOT Modifications. (Bridge(s) (Structure(s)) is (are) designed for Seismic Performance Category B). *((Use note only when designing for Seismic Performance Category B. Do not show note when designing for Seismic Performance Category A.)) ((Use when structure is designed for ASD))*

AASHTO LRFD Bridge Design Specifications, 6th Edition, 2012; and VDOT Modifications *((Use when structure is designed for LRFD))*

Standards: Virginia Department of Transportation Road and Bridge Standards, 2008. *((Use when these standards are needed))*

These plans are incomplete unless accompanied by the Supplemental Specifications and Special Provisions included in the contract documents.

The minimum design life of MSE wall shall be (75-year) (100-year).

The maximum allowable foundation bearing pressure shall be _____ tons/sq. ft. *((Add table if allowable bearing pressure varies along wall alignment.))((For project designed for ASD))*

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

For bearing requirements, see the MSE Wall Bearing Resistance Data Table. *((For project designed for LRFD))*

For settlement requirements, see the Estimated Wall Settlement Table. *((For project designed for LRFD))*

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. 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 shall be removed and replaced with select material Type I minimum CBR of 30. *((Use note where marginal foundation conditions exist or zones of unsuitable material maybe encountered.))*

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

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 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.

Rustication treatment shall be ______________. Forms and liners shall be approved by the Engineer.

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

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

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

A 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*)).

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

Corrosion resistant reinforcing steel shall be used in (copings) (facing panels) and __________.
((Corrosion resistant reinforcing steel *is required in area of heavy salt or chemical spray*)).

(Coping) (Parapet) (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 for the Contract Plans:

MSE WALL BEARING RESISTANCE DATA TABLE

Support Location	Load and Resistance Factor Design (LRFD)	
	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.

ESTIMATED WALL SETTLEMENT TABLE 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 (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. Total settlement also includes secondary consolidation till 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.

The "waiting" period starts when the survey readings at the completion of the wall construction are obtained and shall continue until the required waiting period has been completed and the Geotechnical Engineer of Record reviews the data and confirms that the rate of settlement has stabilized, primary consolidation or elastic settlement is complete and that the remaining long-term settlement will not exceed the allowable amount.

Survey readings shall be taken bi-weekly during wall construction and weekly thereafter until the waiting period is complete.

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

SAMPLE THREE-LINE DRAWING FOR ALTERNATE WALL BID DOCUMENT

UNDER DEVELOPMENT

MSE WALL CONTRACT DRAWING (3-LINE DRAWING) REVIEW CHECKLIST

Project name:	
Project number:	
PPMS:	
Review Date:	

		Yes	No	N/A	Comments
A	GENERAL INFORMATION				
1	Is the wall systems listed in the plan pre-approved within the limitations of the systems?	☐	☐	☐	
2	Is the entire wall (including the reinforced mass) located within the Department's right-of-way?	☐	☐	☐	
3	Is the wall design life specified?	☐	☐	☐	
4	Is rustication treatment of wall face required?	☐	☐	☐	
B	CALCULATIONS				
1	Has bearing capacity calculations been performed to determine the maximum allowable bearing capacity at the estimate bearing stratum?	☐	☐	☐	
2	Is the maximum applied bearing pressure imposed on the bearing stratum less than the calculated maximum allowable bearing capacity?	☐	☐	☐	
3	Has total and differential settlements been calculated?	☐	☐	☐	
4	Has time-rate of settlement been estimated?	☐	☐	☐	
5	Has appropriate action been implemented per VDOT's Requirements for Preparation of Alternate Retaining Wall Plans based on the magnitude of estimated settlement?	☐	☐	☐	
6	Is waiting period for installing coping, parapet, barrier, moment slab, paving etc. required after wall completion?	☐	☐	☐	
7	Is eccentricity of reinforced mass within allowable limits?	☐	☐	☐	
8	Is safety factor of sliding acceptable?	☐	☐	☐	
9	Has global stability calculation been performed?	☐	☐	☐	
C	ELEVATION/PROFILE				
1	Has the designer showed the correct begin and end stations and horizontal offset for wall?	☐	☐	☐	
2	Is the wall on horizontal curve?	☐	☐	☐	
3	If wall is in horizontal curve, has actual wall length been adjusted based on curve geometrics?	☐	☐	☐	
4	Has the designer used the correct design grades in front of wall (e.g. existing ground elevations or proposed grades) for wall design?	☐	☐	☐	
5	Has the designer used the correct design grades at the top of wall for wall design?	☐	☐	☐	
6	Is the wall embedment adequate?	☐	☐	☐	

		Yes	No	N/A	Comments
7	If there are pipes and utilities that will be penetrating the wall or behind the wall, have the locations of these pipes shown in the plans?	☐	☐	☐	
8	Has the maximum allowable bearing capacity along the wall been stated on the plans?	☐	☐	☐	
9	Are estimated settlements along the wall shown in the plans?	☐	☐	☐	
D	CROSS SECTION/DETAILS				
1	Are wall limits for payment correctly shown in cross section?	☐	☐	☐	
2	Are the select backfill dimension shown in cross section?	☐	☐	☐	
3	Are the leveling pad type and dimensions shown in cross section?	☐	☐	☐	
4	Has the type (cast-in-place or precast) of parapet and coping specified?	☐	☐	☐	
5	If parapet or barrier is required, has the dimension, reinforcing steel, etc. been detailed in the plans?	☐	☐	☐	
6	If ground improvement (such as over-excavation and replacement) is required, have the details of ground improvement been shown in the plans?	☐	☐	☐	
E	PAY ITEMS				
1	Is the wall face area pay item in plan quantity item?	☐	☐	☐	
2	Are other quantities (parapet/railing, undercut, and backfill, etc.) listed in accordance with the method of payment in special provision and VDOT Road and Bridge Specifications?	☐	☐	☐	

MSE WALL SHOP DRAWING REVIEW CHECKLIST

Project name:	
Project number:	
PPMS:	
Review Date:	

		Yes	No	N/A	Comments
A	GENERAL INFORMATION				
1	Is the wall systems listed in the contract drawings?	☐	☐	☐	
B	MATERIAL REQUIREMENTS				
	Have the following items been specified in the shop plans and are they in conformance with the project requirements?				
1	Reinforced backfill properties (strength, gradation, PI, electromechanical)	☐	☐	☐	
2	Soil reinforcement (ultimate, yield, allowable strengths, reduction factors for geosynthetics)	☐	☐	☐	
3	Concrete (strength and other properties)	☐	☐	☐	
4	Concrete reinforcement (type, number, and strength)	☐	☐	☐	
5	Leveling pad (type and strength)	☐	☐	☐	
C	FACING UNITS and JOINTS				
1	Do facing units meet the project aesthetic criteria (color and pattern)?	☐	☐	☐	
2	Are the materials properties of the facing units in conformance with project criteria? (Example: strength, freeze-thaw, etc)	☐	☐	☐	
3	Is the joint width between facing unit consistence with estimated differential settlement?	☐	☐	☐	
4	Is the structural thickness (excluding aesthetic thickness) of precast concrete panel facing unit adequate?	☐	☐	☐	
D	DRAINAGE				
1	Are all vertical and horizontal joints covered with geotextile fabric on the backside of the precast concrete panel units?	☐	☐	☐	
2	Is the geotextile fabric covering the joints of sufficient width and continuous across the joints?	☐	☐	☐	
3	If segmental block units are used for facing then has adequate drain fill been provided?	☐	☐	☐	

E	PARAPET/MOMENT SLAB	Yes	No	N/A	Comments
1	Is the parapet/coping type (cast-in-place or precast) in conformance with contract drawings?	☐	☐	☐	
2	Are appropriate joint fillers and bond breakers provided in the interface of moment slab and concrete panel facing units?	☐	☐	☐	
3	Is minimum length of moment slab adequate?	☐	☐	☐	
4	Is moment slab width adequate?	☐	☐	☐	
5	Is waiting period required before installing moment slab and parapet?	☐	☐	☐	
6	Is moment slab conflict with approach slab or pavement?	☐	☐	☐	
F	SPECIAL WALL DETAILS				
1	Are the following special wall details shown and are they adequate?				
	a. special facing unit if interfacing with other walls	☐	☐	☐	
	b. slip joint(s)	☐	☐	☐	
	c. connection to appurtenances (large obstructions and pipe penetrating wall facing)	☐	☐	☐	
	d. acute angles	☐	☐	☐	
	e. measures to prevent migration of de-icing salts in the reinforced fill	☐	☐	☐	
	f. measure to prevent against rapid drawdown conditions and hydrostatic pressures	☐	☐	☐	
2	Are structural frame (“yokes”) provided to navigate the bar mat soil reinforcements around vertical obstructions within the reinforced fill?	☐	☐	☐	
3	Are the structural frames designed properly so that moments and torques are not introduced in the bar mat soil reinforcement and/or the reinforcement/facing unit connection?	☐	☐	☐	
4	Is the splay of strip reinforcements limited to less than 5 degrees?	☐	☐	☐	
5	If strip reinforcement are splayed, then is the length increased to compensate for reduction in effective length?	☐	☐	☐	
6	Is the maximum vertical bend (max. 15 degrees) in metallic soil reinforcement within acceptable limits?	☐	☐	☐	
7	Are geosynthetic reinforcement details around vertical obstructions acceptable?	☐	☐	☐	
8	If walls are tiered or on slope, is bench width adequate?	☐	☐	☐	
9	If instrumentation is required per contract drawings, then is it incorporated in plans?	☐	☐	☐	

G	SOIL REINFORCEMENT	Yes	No	N/A	Comments
1	Is the soil reinforcement type (extensible or inextensible) and configuration (strip, grid or sheet) in conformance with pre-approved list?	☐	☐	☐	
2	Are the following soil reinforcement dimension adequate?				
	a. strip thickness and bar diameter	☐	☐	☐	
	b. strip width or bar mat width	☐	☐	☐	
	c. center to center spacing of the longitudinal bars in bar mats	☐	☐	☐	
	d. center to center spacing of the transverse bars in bar mats	☐	☐	☐	
3	Is the connection of the soil reinforcement to the facing units as per the pre-approved connection detail?	☐	☐	☐	
4	If metallic soil reinforcement are cut and/or spliced then have the corrosion protection measures at cuts/connections been provided and are they acceptable?	☐	☐	☐	
5	Are means and methods for splicing of geosynthetic reinforcement (overlap, mechanical connection, edge seams, etc.) in accordance with project criteria?	☐	☐	☐	
6	Is the soil reinforcement shown in plans match with the type and number of soil reinforcement required in calculations?	☐	☐	☐	
H	CALCULATIONS				
1	Have all the critical sections along all walls been analyzed? (highest wall sections, sections where slopes above are steepest, etc)	☐	☐	☐	
2	Are corrosion loss rates in conformance with project criteria?	☐	☐	☐	
3	Is the correct value of allowable strength of steel used? (e.g. 0.55Fy for strips and 0.48Fy for bar mats)	☐	☐	☐	
4	Has the cross-sectional area for soil reinforcement been corrected for corrosion losses over the design life of the structure?	☐	☐	☐	
5	Are the safety factors against tensile failure adequate at each level of reinforcement?	☐	☐	☐	
6	Are the connections designed for maximum tension in soil reinforcements?	☐	☐	☐	
7	Have the proper values of F^* been used?	☐	☐	☐	
8	Is the correct value for the scale correction factor, α, been used?	☐	☐	☐	
9	For geosynthetic reinforcement have the reduction factors for creep (RF_{CR}), durability (RF_D) and installation damage (RF_{ID}) been specified and are they acceptable?	☐	☐	☐	

		Yes	No	N/A	Comments
10	Has the correct stress ratio (K_r/K_a) been used for computing internal loads?	☐	☐	☐	
11	Has the corrected internal failure surface been used for static and seismic cases?	☐	☐	☐	
12	Has the vertical stress been computed as per the requirements of AASHTO method?	☐	☐	☐	
13	Have all the external loads been incorporated into the wall analysis and design? (e.g. traffic impact loads, sloping surcharge, seismic loads, etc.)	☐	☐	☐	
14	Have all the internal loads been incorporated into wall analysis and design? (e.g. lateral loads from piles at abutments or overhead mast structure)	☐	☐	☐	
15	Has the internal stability evaluation accounted for complex geometries such as acute corners, obstructions?	☐	☐	☐	
16	For fully integral abutment MSE walls, has soil reinforcement designed to resist additional lateral load from piles supporting abutments?	☐	☐	☐	

MSE WALL CONSTRUCTION INSPECTION CHECKLIST

Project name:	
Project number:	
PPMS:	
Review Date:	

A	CHECKLIST FOR DRAWING REVIEW	Yes	No	N/A	Comments
1.0	**DOCUMENTS**				
1.1	Have you thoroughly reviewed the design drawings?	☐	☐	☐	
1.2	Is there a set of all project drawings in the field office?	☐	☐	☐	
1.3	Has the contractor submitted shop drawings?	☐	☐	☐	
1.4	Have the shop drawings been approved by VDOT?	☐	☐	☐	
2.0	**LAYOUT**				
2.1	Have you located the horizontal and vertical control points?	☐	☐	☐	
2.2	Do you know where the MSE wall begins and ends?	☐	☐	☐	
2.3	Have you identified any locations of existing utilities, signs, piles, lights that affect the proposed construction?	☐	☐	☐	
2.4	Have you identified the elevations/grade at top and bottom of MSE wall?	☐	☐	☐	
2.5	Have you identified the existing and finished grades?	☐	☐	☐	
2.6	Do you know where the construction limits are?	☐	☐	☐	
2.7	Have you identified how the site will be accessed and any provisions for material storage?	☐	☐	☐	
2.8	Is phrased construction involved?	☐	☐	☐	
3.0	**FOUNDATION PREPARATION**				
3.1	Are any special foundation treatments required?	☐	☐	☐	
3.2	Is the foundation stepped?	☐	☐	☐	
3.3	Is a leveling pad required?	☐	☐	☐	
3.4	What is the leveling pad made from?	☐	☐	☐	
3.5	Is shoring required?				
4.0	**DRAINAGE**				
4.1	Have you located the details for drainage?	☐	☐	☐	
4.2	When must the drainage provisions be installed?	☐	☐	☐	
4.3	Where does the drainage system outlet?	☐	☐	☐	
4.4	Are geotextile filters required?	☐	☐	☐	
4.5	Is a drainage barrier (geomembrane) required for this project?	☐	☐	☐	

5.0	FACING	Yes	No	N/A	Comments
5.1	Have you identified the facing type, shape, size, and architectural FINISHING?	☐	☐	☐	
5.2	Are there different types, colors, or sized facing units on the jobs?	☐	☐	☐	
5.3	How do the facing units fit together?	☐	☐	☐	
5.4	Do you understand any corner/curve details?	☐	☐	☐	
5.5	Do you understand bracing and shimming requirements?	☐	☐	☐	
5.6	Is the facing battered?	☐	☐	☐	
6.0	**REINFORCING**				
6.1	What type of reinforcement is used in this project?	☐	☐	☐	
6.2	Can you determine the length, location and type of reinforcement throughout the length and height of the wall?	☐	☐	☐	
6.3	Do you understand how the reinforcing connects to the facing?	☐	☐	☐	
6.4	Have you identified any details for avoiding obstructions when placing reinforcement?	☐	☐	☐	
7.0	**BACKFILL**				
7.1	Are different types of fill required in different locations in the wall?	☐	☐	☐	
8.0	**ANCILLARY ITEMS**				
8.1	Is there any coping specified in the drawing?	☐	☐	☐	
8.2	Is there any traffic barrier or guard rail specified in the drawing?	☐	☐	☐	
8.3	Have you identified any junctions at CIP structures?	☐	☐	☐	
8.4	Do you understand the details for connections to CIP structures?	☐	☐	☐	
8.5	Are catch basins/drop inlets involved in this project?	☐	☐	☐	
8.6	Are culverts/pipes involved in this project?	☐	☐	☐	
8.7	Are piles/drilled shafts involved in this project?	☐	☐	☐	
8.8	Are utilities and other obstructions involved in this project?	☐	☐	☐	
8.9	Have you identified and do you understand any special detail to accommodate these obstructions?	☐	☐	☐	
8.10	Do you know who is responsible for installation of each ancillary item?	☐	☐	☐	
8.11	Are diversion ditches, collection ditches, or slope drains shown on the drawings?	☐	☐	☐	
8.12	Is a permanent or temporary erosion control blanket required?	☐	☐	☐	
8.13	Do you understand any erosion control details?	☐	☐	☐	

B	CHECKLIST FOR DRAWING REVIEW	Yes	No	N/A	Comments
1.0	**DOCUMENTS**				
1.1	Have you thoroughly reviewed the specifications?	☐	☐	☐	
1.2	Is there a set of specifications in the field office?	☐	☐	☐	
1.3	Are standard specifications or special provisions required in addition to the project specifications? Do you have a copy?	☐	☐	☐	
2.0	**PRE-CONSTRUCTION QUALIFYING OF MATERIAL SOURCES/SUPPLIERS**				
2.1	Has the Contractor submitted reinforced soil pre-construction qualification test results (showing that it meets the gradation, density, corrosivity, and other soil-property requirements)?	☐	☐	☐	
2.2	Has the Contractor submitted reinforced soil pre-construction qualification test results and/or Certification of Compliance demonstrating that the facing materials comply with the applicable sections of the specifications?	☐	☐	☐	
2.3	Has the Contractor or Manufacturer submitted pre-construction qualification test results and/or Certification of Compliance demonstrating that the reinforcing materials comply with the applicable sections of specifications?	☐	☐	☐	
2.4	Has approval of reinforced soil sources been official granted?	☐	☐	☐	
2.5	Has approval of the facing material supplier been officially granted?	☐	☐	☐	
2.6	Has approval of the reinforcing material supplier been officially granted?	☐	☐	☐	
3.0	**FOUNDATION PREPARATION**				
3.1	Has temporary shoring been designed and approval?	☐	☐	☐	
4.0	**DRAINAGE**				
4.1	Do the drainage materials delivered to the site correspond to the approved drawings?	☐	☐	☐	
4.2	Do the identification labeling/markings on the prefabricated drainage materials delivered to the site correspond to the pre-construction and QC submittals (date of manufacturing, lot number, roll numbers, etc)?	☐	☐	☐	
4.3	Have the drainage materials been inspected for damage due to transport or handling?	☐	☐	☐	
4.4	Are the drainage materials properly stored to prevent damage, exposure to UV light, contamination?	☐	☐	☐	

		Yes	No	N/A	Comments
4.5	If any drainage materials were found damaged, have they been set aside, rejected or repaired in accordance with the specifications?	☐	☐	☐	
4.6	Has QA sampling of the drainage materials been preformed at the required frequency?	☐	☐	☐	
4.7	Does the QA lab know exactly which test to run and the require test parameters?	☐	☐	☐	
4.8	Do the QA test results for the drainage materials meet the specified property values?	☐	☐	☐	
5.0	**FACING**				
5.1	Is the Contractor or Manufacturer submitting QC test results at the specified frequency demonstrating that the facing materials comply with the applicable sections of the specifications?	☐	☐	☐	
5.2	Do the facing components delivered to the site correspond to the approved shop drawings (shape, dimensions, reinforcement connections, overall quantity)?	☐	☐	☐	
5.3	Do the identification labeling/markings on the facing components panels delivered to the site correspond to the pre-construction qualification and QC submittals (date of manufacturing, batch number, lot number, etc)?	☐	☐	☐	
5.4	Have the facing components been inspected for damage due to transport, handling, or storage activities?	☐	☐	☐	
5.5	Are the facing components properly stored to prevent damage?	☐	☐	☐	
5.6	If any facing components were found damage, have they been rejected or repaired in accordance with the specifications?	☐	☐	☐	
5.7	Has QA sampling of the facing components been performed at the required frequency?	☐	☐	☐	
5.8	Does the QA lab know exactly which tests to run and the required test parameters?	☐	☐	☐	
5.9	Do the QA test results for the facing materials meet the specified property values?	☐	☐	☐	
6.0	**REINFORCING**				
6.1	Is the Contractor or Manufacturer submitting QC test results at the specified frequency demonstrating that the reinforcing materials comply with the applicable sections of the specifications?	☐	☐	☐	
6.2	Do the facing components delivered to the site correspond to the approved shop drawings (strength, dimensions, overall quantity)?	☐	☐	☐	

		Yes	No	N/A	Comments
6.3	Do the identification labeling/markings on the reinforcing materials delivered to the site correspond to the pre-construction qualification and QC submittals (date of manufacturing, batch number, lot number, etc)?	☐	☐	☐	
6.4	Have the reinforcing materials been inspected for damage due to transport, handling, or storage activities?	☐	☐	☐	
6.5	Are the reinforcing materials properly stored to prevent damage, exposure to UV light, corrosion?	☐	☐	☐	
6.6	If any reinforcing materials were found damage, have they been rejected or repaired in accordance with the specifications?	☐	☐	☐	
6.7	Has QA sampling of the reinforcing materials been performed at the required frequency?	☐	☐	☐	
6.8	Does the QA lab know exactly which tests to run and the required test parameters?	☐	☐	☐	
6.9	Do the QA test results for the reinforcing materials meet the specified property values?	☐	☐	☐	
6.10	If pullout or interface shear testing is required, does the QA lab have enough of the applicable soil and the compaction criteria (in addition to the reinforcing materials)?	☐	☐	☐	
7.0	**BACKFILL**				
7.1	Is the Contractor submitting QC test results of reinforced soil at the specified frequency?	☐	☐	☐	
7.2	Does the QA lab know exactly which test to run and the required test parameters?	☐	☐	☐	
7.3	Do the QA test results for reinforced soil meet the specified property values?	☐	☐	☐	
8.0	**ANCILLARY ITEMS**				
8.1	Do any ancillary materials delivered to the site correspond to the approved shop drawings (catch basins, pipe, guardrail, etc.)?	☐	☐	☐	
8.2	Do the identification labeling/markings on the ancillary materials delivered to the site correspond to the QC submittals (date of manufacturing, batch number, etc.)?	☐	☐	☐	
8.3	Have the ancillary materials been inspected for damage due to transport, handling, or storage activities?	☐	☐	☐	
8.4	Are the ancillary materials properly stored to prevent damage?	☐	☐	☐	
8.5	If any ancillary materials were found damaged, have they been set aside, rejected, or repaired in accordance with the specifications?	☐	☐	☐	
8.6	Have all requirements to sample/test any aspect of the work product after assembly, installation, compaction been met?	☐	☐	☐	

	CHECKLIST FOR CONSTRUCTION	Yes	No	N/A	Comments
1.0	**LAYOUT**				
1.1	Has the Contractor staked out sufficient horizontal and vertical control points?	☐	☐	☐	
1.2	Has the Contractor account for wall batter when staking the base of the wall?	☐	☐	☐	
1.3	Have all utilities been located and marked?	☐	☐	☐	
1.4	Have erosion and sedimentation controls been installed?	☐	☐	☐	
1.5	Have stockpile and staging areas been discussed and approved?	☐	☐	☐	
1.6	Have access routes and temporary haul roads been discussed and approved?	☐	☐	☐	
2.0	**FOUNDATION PREPARATION**				
2.1	Has the MSE wall foundation area been excavated to the proper elevation?	☐	☐	☐	
2.2	Has the foundation subgrade been inspected (e.g., proof rolled) as required by the specifications?	☐	☐	☐	
2.3	Has all soft or loose materials been compacted or unsuitable materials (e.g. wet soil, organics) been removed or replaced?	☐	☐	☐	
2.4	Has the leveling-pad (if applicable) area been properly excavated and set to the proper vertical and horizontal alignment?	☐	☐	☐	
2.5	Has the leveling pad (if applicable) cured for the specified time before the Contractor sets any facing panels/blocks?	☐	☐	☐	
3.0	**DRAINAGE**				
3.1	Is the drainage being installed in the correct location?	☐	☐	☐	
3.2	Are drainage aggregate being kept free of fine materials?	☐	☐	☐	
3.3	Are all holes, rips and punctures in geotextiles being repaired in accordance with the specifications?	☐	☐	☐	
3.4	Are composite drain materials being placed with the proper side to the seepage face?	☐	☐	☐	
3.5	Do all collection and outlet pipes have a positive slope?	☐	☐	☐	
4.0	**FACING**				
4.1	Is the first row of facing panels (when applicable) properly placed? Do they have proper spacing, batter, and do they have the spacers installed?	☐	☐	☐	
4.2	Is the Contractor using the correct facing unit (correct size, shape, color, and with the proper number of connections) for the applicable location and elevation?	☐	☐	☐	

		Yes	No	N/A	Comments
4.3	Is geotextile filter being properly placed over joints in the facing panels?	☐	☐	☐	
4.4	Is the vertical elevation and horizontal alignment being checked periodically and adjusted as needed?	☐	☐	☐	
4.5	Is the contractor removing the wooden wedges?	☐	☐	☐	
4.6	Is the spacing between (or overlap) individual facing units in accordance with the specifications?	☐	☐	☐	
5.0	**REINFORCING**				
5.1	Is the reinforcement being properly connected (connections tight and all of the slack in the reinforcement layers removed) ?	☐	☐	☐	
5.2	Is the reinforcement in the proper alignment?	☐	☐	☐	
5.3	Is the reinforcement the right type?	☐	☐	☐	
5.4	Is the reinforcement the correct length?	☐	☐	☐	
5.5	Is the reinforcement being placed at the correct spacing and location?	☐	☐	☐	
5.6	Is the fill being brought up to the soil reinforcement elevation before the reinforcement is connected?	☐	☐	☐	
5.7	Is construction equipment being kept from operating on the reinforcement (i.e. until adequate soil cover is placed over the reinforcement)?	☐	☐	☐	
6.0	**BACKFILL**				
6.1	At the end of each day's operation, is the Contractor grading the upper surface of reinforcement and retained soil to ensure runoff of storm water away from MSE wall face or provide a positive means of controlling runoff away from the construction area?	☐	☐	☐	
6.2	Where applicable, has the Contractor backfilled in front of the MSE wall?	☐	☐	☐	
6.3	Is the Contractor placing the reinforced soil in lifts as per special provision?	☐	☐	☐	
6.4	If the Contractor is using water to adjust the moisture of reinforced soil, does it meet the requirements set forth in the special provision?	☐	☐	☐	
6.5	Is the reinforced soil being placed to prevent damage to the reinforcement?	☐	☐	☐	
6.6	Are the lifts being spread to prevent excessive tension or excessive slack in the reinforcement?	☐	☐	☐	
6.7	Is the fill being compacted using the correct equipment and in the correct pattern?	☐	☐	☐	
6.8	Is the soil moisture content within the specified range?	☐	☐	☐	
6.9	Is the soil compaction (dry density) within the specified range?	☐	☐	☐	
6.10	Is large compaction equipment being kept at least 3' from the face?	☐	☐	☐	

		Yes	No	N/A	Comments
7.0	**ANCILLARY ITEMS AND FINISHED PRODUCT**				
7.1	Could installation of ancillary components (e.g. catch basins, storm-water piping, guardrail) affect the reinforcing or facing components already installed?	☐	☐	☐	
7.2	Have ancillary items been installed in accordance with the drawings and specifications?	☐	☐	☐	
7.3	Are ancillary items being installed at the proper locations?	☐	☐	☐	
7.4	Are diversion ditches, collection ditches, or slope drains installed in accordance with the drawings and specifications?	☐	☐	☐	
7.5	Is permanent or temporary erosion control blanket installed at the required locations and using the details shown on the drawings?	☐	☐	☐	
7.6	Are there any visible signs of MSE wall tilting, bulging, or deflecting?	☐	☐	☐	
7.7	Has the vertical and horizontal alignment been confirmed by survey?	☐	☐	☐	
7.8	Is there a need to confirm the vertical or horizontal alignment at the future time to evaluate whether movement is occurring?	☐	☐	☐	
7.9	Are there any signs of distress to the facing components (e.g. fracturing or spalling of concrete panels, cracking of the facing blocks, etc.)?	☐	☐	☐	

VIRGINIA DEPARTMENT OF TRANSPORTATION
SPECIAL PROVISION FOR
MECHANICALLY STABILIZED EARTH WALLS
(CONCRETE PANEL FACING)

1.0 DESCRIPTION

This work shall consist of furnishing and constructing Mechanically Stabilized Earth (MSE) Walls in accordance with these specifications and in reasonably close conformity with the lines, grades, dimensions, and design shown on the plans or established by the Engineer. This specification is intended to cover MSE walls utilizing discrete concrete panel facing as approved by VDOT Structure and Bridge Division.

2.0 SUBMITTALS

The Contractor shall submit working drawings, shop plans, and design calculations, signed and sealed by a Virginia Registered Professional Engineer, to the Engineer for review by the Department. The Contractor shall allow 30 days from the day the submittals are received by the Department for review and approval. Fabrication or any wall construction shall not begin prior to the approval of the design, working drawings and shop plans. Approval of the Contractor's working drawings and shop plans shall not relieve the Contractor of any of his responsibility under the contract for the successful completion of the work.

2.1 Working Drawings and Shop Plans

The working drawings and shop plans shall reflect all information needed to fabricate and erect the walls including:

a. Elevations at the top of wall at all the horizontal and vertical break points and at interval not exceeding 50 feet along the wall;

b. Elevations at the top of leveling pad step breaks;

c. Elevation of the finished grade in front of the wall;

d. The number, size, type, length, and details of the soil reinforcing elements in each design section;

e. The locations and sizes of all pipes and utilities that will be penetrating the wall face or within the soil reinforced mass;

f. Typical cross-section or cross-sections showing the elevation relationship between ground conditions and proposed grades;

g. Details for construction of wall around obstructions (i.e. drainage facilities, utilities, overhead sign footing, piles, drilled shafts) within the reinforced backfill;

h. Details pertaining to coping, parapets, railing, as required by the contract plans;

i. Shape, dimension, and designation of wall panel;

j. Details of the architectural or finish treatment supplied.

2.2 Design Calculations

The proposed design shall satisfy the design parameters and requirements in the plans and in the special provisions. Complete design calculations shall include the most critical geometry and loading combination for each design section that exist during construction and at the end of construction.

3.0 MATERIALS

The Contractor shall make arrangements to purchase or manufacture the facing elements, metallic reinforcing mesh or strips, geosynthetic geogrids, connection devices, joint materials, and all other necessary components. Material not conforming to this section of the specifications shall not be used without the written consent from the Engineer.

3.1 Reinforced Concrete Face Panels

Concrete for face panel units shall be Class A4 conforming to the requirements of Section 217 of the Specifications except that the maximum water/cement ratio shall be 0.47. Panel steel reinforcement shall meet the requirements of Section 223 of the Specifications.

Panel steel reinforcement, connection devices, and lifting devices shall be set in place to the dimensions and tolerances shown on the plans prior to casting.

3.1.1. Testing and Inspection

The Contractor or his supplier shall furnish facilities and shall perform all necessary sampling and testing in an expeditious and satisfactory manner. Panels will be considered acceptable for placement in the wall when control cylinder tests exceed 85% of 28 day design strength requirements.

3.1.2. Casting

Concrete panels shall be cast on a flat area; the front face of the form at the bottom and the back face at the upper part. Galvanized connection devices shall be set on the rear face. The concrete in each unit shall be placed without interruption and shall be consolidated by the use of an approved vibrator, supplemented by such hand-tamping as may be necessary to force the concrete into the corners of the forms and prevent the formation of stone pockets or cleavage planes. Clear form oil of the same manufacture shall be used throughout the casting operation.

3.1.3. Curing

Panel units shall be cured in accordance with the requirements of Section 404.03 (k) of the Specifications. Any panel concrete placement that does not reach specified design strength within 28 days will be rejected as determined by concrete control cylinders.

3.1.4. Removal of Forms

The forms shall remain in place for a minimum of 20 hours or when control cylinder tests indicate that the concrete has attained at least 20% of the 28-day design requirement in accordance with the requirements of Section 404.03 (j) of the Specifications.

3.1.5. Concrete Finish and Tolerances

Unless otherwise shown on the plans, concrete surface for the front face shall be a Class 1 finish conforming to the requirements of Section 404 of the Specifications or as detailed on the plans and a uniform surface finish on the rear face. Rear face of the panel shall be screeded to eliminate open pockets of aggregate and surface distortions in excess of 1/4 inch.

3.1.6. Tolerances

All panel units shall be manufactured within the following tolerances:

- Lateral position of connection devices within 1 inch.
- All other panel dimensions within 3/16 inch.
- Squareness, as determined by the difference between the two diagonals, shall not exceed ½ inch.
- Surface irregularities on smooth formed surfaces measured on a length of 5 feet shall not exceed 1/8 inch. Surface irregularities on textured-finish surfaces measured on a length of 5 feet shall not exceed 5/16 inch.

3.1.7. Rejection

Panel units will be subject to rejection because of failure to meet any of the requirements specified above. In addition, any of the following defects will be sufficient cause for rejection:

- Defects that indicate imperfect molding.
- Defects such as chipped or broken concrete.
- Defects indicating honeycombed or open texture concrete.
- Color variations on the front face of panel due to excess form oil or other reason.

3.1.8. Marking

The date of manufacture, production lot number, and piece mark shall be clearly scribed on the rear face of each panel unit.

3.1.9. Handling, Storage and Shipping

All panel units shall be handled, stored and shipped in such manner as to eliminate the danger of chipping, cracks, fractures and excessive bending stresses. Panel units shall be removed from casting beds by an approved four-point pick up method. Panel units in storage shall be supported on firm blocking to protect the panel connection devices and the exposed exterior finish.

3.2 Steel Soil Reinforcing and Connection Devices

3.2.1 Metallic Reinforcing Strips

Reinforcing strips shall be hot rolled or cold formed from bars or coil to the required shape and dimensions. Their physical and mechanical properties shall conform to ASTM A-36, ASTM A-572 Grade 65, or ASTM A-1011 Grade 65. Galvanization for reinforcing strips shall conform to the requirements of ASTM A-123 and the minimum coating thickness shall be 2 oz/sf (or 3.4 mils).

3.2.2 Metallic Reinforcing Mesh and Bar Mats

Reinforcing mesh shall be shop fabricated of cold drawn steel wire conforming to the requirements of ASTM A-82 and shall be welded into the finished mesh fabric in accordance with the requirements of ASTM A-185, except that, the minimum average shear stress of the weld shall be at least 35,750 psi. The reinforcing mesh manufacturer shall provide certification that the minimum average weld shear strength is adequate for the proposed design and provides a reasonable safety factor.

Galvanization shall be applied after the mesh is fabricated and conform to the requirements of ASTM A-123 and the minimum coating thickness shall be 2 oz/sf (or 3.4 mils). Any damage to the galvanizing shall be repaired in accordance with the requirements of Section 233 of the Specifications.

3.2.3 Tie Strips/Lug

Tie strips/lug shall be shop fabricated of hot rolled or cold formed steel conforming to the requirements of ASTM A-570, Grade 50 or ASTM A-1011 Grade 50. Galvanization shall conform to ASTM A-123 and the minimum coating thickness shall be 2 oz/sf (or 3.4 mils).

3.2.4 Fasteners

Bolts and nuts shall conform to the requirements of ASTM A-325, ASTM A-449, or ASTM A-563 and shall be galvanized in accordance with ASTM A-153 and minimum coating thickness of 2 oz/sf (or 3.4 mils).

3.2.5 Connection Devices

Connection loop shall be fabricated of cold drawn steel wire conforming to the requirements of ASTM A-82 and welded in accordance with the requirements of ASTM A185. Connector bars shall be fabricated of cold drawn steel wire conforming to the requirements of ASTM A-82 and galvanized in accordance with ASTM A-123.

All connection devices shall be galvanized in accordance with the requirements of ASTM A-123 or approved equal and minimum coating thickness shall be 2 oz/sf (or 3.4 mils).

3.3 Geosynthetic Soil Reinforcing and Connection Devices

3.3.1 Geogrids

Geogrids shall be structural geogrids formed by uniaxially drawing a continuous sheet of high density polyethylene material. Geogrids shall be a regular network of integrally connected polymer tensile elements with aperture geometry sufficient to permit significant mechanical interlock with the surrounding soil or rock. Structure of geogrid reinforcement shall be dimensionally stable and able to retain its geometry under manufacture, transport and installation.

3.3.2 Delivery, Storage, and Handling

The Contractor shall check the geogrid reinforcement upon delivery to assure that the proper grade and type of material has been received. Rolled geogrid shall be stored in accordance with the manufacture's recommendations. During all period of shipment and storage, geogrid reinforcement shall prevent wet cement, epoxy and like materials from coming in contact with and affixing to the geogrids.

3.3.3 Connection Devices

Connection devices, such as bars, pins, plates etc, shall consist of non-degrading polymer and be made for the express use with the geogrids supplied.

3.4 Joint Materials

3.4.1. Joint Cover

If required, cover all joints between panels on the back side of the wall with a geotextile meeting the requirements for drainage fabric as specified in Section 245. Use adhesive approved by the manufacturer to attach the geotextile to the panel. The minimum width and lap shall be 12 inches.

3.4.2. Bearing Pads

Provide in horizontal joints between panels preformed EPDM rubber pads conforming to ASTM D-2000 for 4AA, 812 rubbers, neoprene elastometric pads having a Durometer Hardness of 55±5, or high density polyethylene pads with a minimum density of 59.06 lb/ft^3 in accordance with ASTM 1505.

3.4.3 Joint Filler

If required, provide flexible foam strips as recommended by wall manufacturer for filler for vertical and inclined joints between panels, and in horizontal joints where pads are used, where indicated on the plans.

3.5 Select Backfill Material

Select backfill material used in the structure volume shall be reasonably free from organic material, shale or other poor durability particles and otherwise deleterious materials. The backfill shall conform to the following grading as determined by AASHTO T-27:

Sieve Size	Percent Passing
4"⁺	100
No. 40	0 - 60
No. 200	0 - 15

⁺ The maximum soil particle size for polymeric geogrid reinforcement shall be 3/4 inch unless full scale installation damage tests are conducted in accordance with ASTM D5818.

The Plasticity Index (P.I.) of the backfill material as determined by AASHTO T-90 shall not exceed 6.

Backfill material shall exhibit an angle of internal friction of not less than 34 degrees, as determined by the standard Direct Shear Test, AASHTO T236, on the portion finer than the #10 sieve, using a sample of the material compacted to 95 percent of AASHTO T99, Methods C or D, with oversized correction as outlined in Note 7, at optimum moisture content. No testing is required for material where 80 percent of sizes are greater than 3/4 inch.

Backfill material shall have a magnesium sulfate soundness loss of less than 30 percent after four cycles.

Additionally, the backfill material shall conform to the following electrochemical requirements:

- For metallic soil reinforcements:

Requirements	AASHTO Test Methods
a) pH range between 5.0 and 10.0	T289
b) Resistivity greater than 3,000 ohm-cm	T288
c) Chlorides less than 100 ppm	T291
d) Sulfates less than 200 ppm	T290
e) Organic Content less than 1%	T267

If resistivity is greater or equal to 5000 ohm-cm, the chlorides and sulfates requirements may be waived.

- For geosynthetic soil reinforcements:

<u>Polyolefin Polymer (Polypropylene and High Density Polyethylene):</u>

Requirement	AASHTO Test Methods
a) pH range between 3.0 and 11.0	T289

The Contractor shall perform analysis tests for each source of material and shall perform such additional tests to assure conformance whenever the character of the select backfill material changes. All tests shall be performed by laboratories that are AASHTO Materials Reference Laboratory (AMRL) accredited.

The Contractor shall furnish the Engineer a Certificate of Compliance certifying the furnished select backfill materials comply with the aforementioned requirements. Test results performed by the Contractor necessary to assure contract compliance shall also be furnished the Engineer.

3.6 Cast-In-Place Concrete

Concrete for leveling pads and wall top coping shall be Class A3 conforming to the requirements of Section 217 of the Specifications.

3.7 Moment Slab Reinforcing Steel

Corrosion resistant reinforcing (CRR) steel shall be used in moment slab and shall be the same type of CRR steel specified for parapet as shown on plans.

4.0 CONSTRUCTION REQUIREMENTS

4.1 Wall Excavation

Wall excavation shall be unclassified in accordance with the requirements of Sections 506 and 401 of the Specifications and shall be performed in reasonably close conformity to the limits and construction stages shown on the plans.

4.2 Foundation Preparation

The foundation for the structure shall be graded level for a width equal to or exceeding the length of reinforcement or as shown on the Plans. Prior to wall construction, the foundation shall be compacted in accordance with the embankment requirements of Section 303.04 (h) of the Specifications and graded to a relatively smooth and uniform surface. Any foundation soils found to be unsuitable shall be removed and replaced with select backfill as per Materials of these specifications.

At each panel foundation level, an unreinforced concrete leveling pad shall be provided as shown on the plans. Leveling pads shall be level within 1/8 inch per pad or per 100 feet, whichever is greater. The pad shall be cured a minimum of 12 hours before placement of wall panels.

4.3 Wall Erection

Precast concrete panels shall be placed vertically with the aid of a crane or other suitable equipment. For erection, panels shall be handled by means of a lifting device set into the upper edge of the panels. Panels shall be placed in successive horizontal lifts in the sequence shown on the plans as backfill placement proceeds. As fill material is placed behind a panel, the panels shall be maintained in vertical position by means of temporary wooden wedges placed in the joint at the junction of the two adjacent panels on the external side of the wall. External bracing may also be required for the initial lift. Vertical tolerances (plumbness) and horizontal alignment tolerance shall not exceed 3/4 inch when measured along a 10-foot straight edge. The maximum allowable lateral offset at any panel joint shall be 3/4 inch. The overall vertical tolerance of the wall (plumbness from top to bottom) shall not exceed ½ inch per 10 feet of wall height.

4.4 Select Backfill Placement

The placement of the select backfill material shall closely follow the erection of each lift of panels. At each reinforcing element level, backfill shall be roughly leveled before placing and attaching reinforcement to the panel. Unless otherwise shown on the plans, reinforcement shall be placed normal to the face of the wall. The maximum lift thickness shall not exceed 8 inches loose and shall closely follow panel erection. The Contractor shall decrease this lift thickness if necessary to obtain the specified density.

Backfill shall be compacted to 95% of the maximum density as determined by AASHTO T-99, Method C or D with oversize correction as outlined in Note 7. For backfills containing more than 80 percent material retained on the 3/4 inch sieve, a method of compaction consisting of at least four passes with a heavy roller shall be used. For applications where spread footings are used to support bridge or other structural loads, the top 5 feet below the footing elevation shall be compacted to 100 percent AASHTO T-99. The moisture content of the backfill material prior to and during compaction shall be uniformly distributed throughout each layer. Backfill material shall have a placement moisture content equal to the optimum moisture content. Moisture content may be up to 2 percentage points less than optimum moisture content.

Prior to placement of any backfill, geogrid shall be pulled taut to remove slack. The backfill shall be placed in a manner that geogrid remains taut. Tracked construction equipment shall not operate directly on geogrid. A minimum fill thickness of 6 inches over the geogrid is required prior to operation of tracked vehicles. Rubber tired equipment may pass over the geogrid at speeds less than 10 mph. Sudden braking and sharp turning shall be avoided.

At the end of each day's operations, the Contractor shall shape the last level of backfill as to permit runoff of rainwater away from the wall face. Backfill compaction shall be accomplished without disturbance or distortion of reinforcing elements and panels. Compaction adjacent to the backside of the wall in a strip 3 feet wide shall be achieved using mechanical hand tampers. No compaction density tests are required within 3 feet from the back face of wall.

4.5 Cast-In-Place Concrete

Concrete work for leveling pads and wall top coping shall be performed in accordance with the requirements of Section 404 of the Specifications.

5.0 MEASUREMENT AND PAYMENT

The quantity of Mechanically Stabilized Earth (MSE) walls to be paid for will be the plan quantity, in units of square feet of retaining structure, as shown on the contract drawings. Unless otherwise defined on the plans, payment shall be full compensation for all excavation; temporary shoring when not specified on the wall plans or in the proposal as a separate pay item; concrete footing; leveling pads; face panels; copings and moment slabs; masonry; reinforcing steel; steel or geosynthetic soil reinforcements, select backfill material; backfilling; compaction; joint materials; riprap to fill temporary excavation, including all work necessary outside the retainage area shown on the plans; disposal offsite or onsite, where permitted by the Engineer, of unsuitable or surplus material; and all materials, labor, tools, equipment, and incidentals necessary to complete the work.

Payment will be made under:

Pay Item	Pay Unit
Retaining Structure	Square foot

VIRGINIA DEPARTMENT OF TRANSPORTATION
SPECIAL PROVISION FOR
MECHANICALLY STABILIZED EARTH WALLS
(SEGMENTAL BLOCK FACING)

1.0 DESCRIPTION

This work shall consist of furnishing and constructing Mechanically Stabilized Earth (MSE) Walls with segmental concrete block facing in accordance with these specifications and in reasonably close conformity with the lines, grades, dimensions, and design shown on the plans or established by the Engineer. This specification is intended to cover MSE wall systems utilizing segmental block facing as approved by VDOT Structure and Bridge Division.

2.0 SUBMITTALS

The Contractor shall submit working drawings, shop plans, and design calculations, signed and sealed by a Virginia Registered Professional Engineer, to the Engineer for review by the Department. The Contractor shall allow 30 days from the day the submittals are received by the Department for review and approval. Fabrication or any wall construction shall not begin prior to the approval of the design, working drawings and shop plans. Approval of the Contractor's working drawings and shop plans shall not relieve the Contractor of any of his responsibility under the contract for the successful completion of the work.

2.1 Working Drawings and Shop Plans

The working drawings and shop plans shall reflect all information needed to fabricate and erect the walls including:

a. Elevations at the top of wall at all the horizontal and vertical break points and at interval not exceeding 50 feet along the wall;

b. Elevations at the top of leveling pad step breaks;

c. Elevation of the finished grade in front of the wall;

d. The number, size, type, length, and details of the soil reinforcing elements in each design section;

e. The locations and sizes of all pipes and utilities that will be penetrating the wall face or within the soil reinforced mass;

f. Typical cross-section or cross-sections showing the elevation relationship between ground conditions and proposed grades;

g. Details for construction of wall around obstructions (i.e. drainage facilities, utilities, overhead sign footing, piles, drilled shafts) within the reinforced backfill;

h. Details pertaining to coping, parapets, railing, fencing as required by the contract plans;

i. Shape, dimension, color, and designation of segmental blocks and alignment and connection devices.

2.2 Design Calculations

The proposed design shall satisfy the design parameters and requirements in the plans and in the special provisions. Complete design calculations shall include the most critical geometry and loading combination for each design section that exist during construction and at the end of construction.

2.3 Supporting Documents and Testing Reports

For segmental block or soil reinforcement systems that are not in VDOT approved list, the following design parameters and supporting documents and testing reports shall be submitted to the Engineer for review:

a. Certifications of Ultimate Tensile Strength (T_{ULT}). Ultimate tensile strength shall be the minimum average roll values (MARV) and determined from wide width tensile test in accordance with ASTM D-6637.

b. The values of Creep Reduction Factor (RF_{CR}). RF_{CR} shall be determined from creep tests performed in accordance with ASTM D-5262.

c. The values of Installation Damage Reduction Factor (RF_{ID}). RF_{ID} shall be determined from field and laboratory test results and literature review, as described in ASTM D 5818 for MSE wall select backfill specified or for more severe soils.

d. The values of Durability Reduction Factor (RF_D). RF_D shall be defined as the combined effects of chemical and biological degradation. Laboratory test results, extrapolation techniques, and comprehensive literature review shall document RF_D for all material components in accordance with Section 3.5 of FHWA NHI-10-024, "Design and Construction of Mechanically Stabilized Earth Walls and Reinforced Soil Slopes.

e. The values of Long-term Connection Strength Reduction Factors (CR_{cr}). CR_{cr} shall be determined in accordance with the long-term connection strength protocol as described in Appendix B.3 of FHWA NHI-10-024 "Design and Construction of Mechanically Stabilized Earth Walls and Reinforced Soil Slopes".

3.0 MATERIALS

The Contractor shall make arrangements to purchase or manufacture the facing elements, soil reinforcement, connection devices, cap block adhesive, and all other necessary components. Material not conforming to this section of the specifications shall not be used without the written consent from the Engineer.

3.1 Segmental Concrete Blocks

Dry-cast segmental concrete blocks shall be made of hydraulic cement concrete with a minimum 28-day compressive strength of 4000 psi. Maximum water absorption limit shall be 5%.

When concrete block freeze-thaw test is required on the plans, dry-cast concrete blocks shall be tested in accordance with ASTM C1262 to demonstrate durability. The concrete block shall meet the requirements of ASTM C1372, except that acceptance regarding durability of dry-cast blocks under ASTM C1262 shall be achieved if the weight loss of each of four of the five specimens at the conclusion of 150 cycles does not exceed 1% of its initial weight when tested in water. Dry-cast blocks shall also meet the additional requirements of ASTM C 140.

Wet-cast segmental concrete blocks shall be cast with Class A4 hydraulic cement concrete conforming to the requirements of VDOT Road and Bridge Specifications Section 217.

3.1.1. Inspection, Sampling and Testing

The Contractor or his supplier shall furnish facilities and shall perform all necessary sampling and testing in an expeditious and satisfactory manner. Acceptance of dry-cast concrete blocks with respect to compressive strength will be determined on a lot basis. The maximum number of dry-cast blocks in each lot shall be 5,000. The lot will be randomly sampled in accordance with ASTM C-140. Compressive strength tests shall be preformed by the supplier and approved by the Engineer. Dry-cast blocks compressive strength test specimens shall be cored or shall conform to the saw-cut coupon provisions of Section 5.2.4 of ASTM C-140. Dry-cast blocks represented by three test coupons shall have an average compressive strength of 4000 psi and all individual coupons shall have compressive strength of 3500 psi.

Concrete for wet-cast segmental blocks shall be sampled and tested in accordance with VDOT Road and Bridge Specifications Section 217.08.

3.1.2. Casting

Segmental concrete blocks shall be cast in steel mold and in a manner that will assure the production of uniform segmental concrete blocks. The concrete in each block shall be placed without interruption and shall be consolidated by the use of an approved method.

3.1.3. Finish and Appearance

Unless otherwise shown on the plans or directed by the Engineer, concrete surfacing for the front face of the block shall be natural gray fractured rock face finish. All units shall be sound and free of cracks or other defects that would interfere with the proper placing of the unit or significantly impair the strength or permanence of the construction.

3.1.4. Tolerances

Notwithstanding any requirement of any reference standard applied within this specification, all block units shall be manufactured within the following tolerances:

For concrete block with front face area less than 5 square feet:

- The height, length, and width of each individual block shall be within ±1/8 inch of the specified dimension. Hollow units shall have a minimum wall thickness of 1-1/4 inches.

For concrete block with front face area of 5 square feet or more:

- The length and width of each individual block shall be within ±1/2 inch and 1 inch of the specified dimensions, respectively.

- The height of each individual block shall be within ±3/16 inch of the specified dimension.

(Length refers to the horizontal dimension of the block measured parallel to the running length of the wall. Width refers to the horizontal dimension of the block measured perpendicular to the face of the wall from the exposed surface to the back of the block.)

3.1.5. Rejection

Segmental concrete blocks will be subject to rejection because of failure to meet any of the requirements specified above. In addition, any of the following defects will be sufficient cause for rejection:

- Defects that indicate imperfect molding.
- Cracked greater than 0.02 inch in width and longer than 25% of the height of the block.
- Severely chipped or broken blocks.
- Defects indicating honeycombed or open texture concrete.
- Color variations on front face of block due to excess form oil or other reason.

3.1.6. Marking

The date of manufacture, production lot number, and type of block in accordance with the approved design drawings shall be clearly marked on each lot.

3.1.7. Handling, Storage and Shipping

Segmental concrete blocks shall be handled, stored and shipped in such manner as to eliminate the dangers of chipping, cracks, fractures and discoloration.

3.2 Geogrid Reinforcement

Geogrids shall be a regular network of integrally connected polymer tensile elements with aperture geometry sufficient to permit significant mechanical interlock with the surrounding soil or rock. Structure of geogrid reinforcement shall be dimensionally stable and able to retain its geometry under manufacture, transport and installation.

3.2.1 Delivery, Storage, and Handling

The Contractor shall check the geogrid reinforcement upon delivery to assure that the proper grade and type of material has been received. Rolled geogrid shall be stored in accordance with the manufacture's recommendations. During all period of shipment and storage, geogrid reinforcement shall prevent wet cement, epoxy and like materials which may affix themselves, from coming in contact with the geogrids.

3.3 Steel Mesh Reinforcement

Inextensible metallic mesh design requirements shall be as shown in the plans and specified in the design drawings. Metallic mesh reinforcement shall be shop fabricated of cold drawn steel wire conforming to the requirements of ASTM A-82 and shall be welded into the finished mesh fabric in accordance with the requirements of ASTM A-185. Mill certification containing the yield strength of the mesh reinforcement shall be provided.

Galvanization shall be applied after the mesh is fabricated and conform to the requirements of ASTM A-123. Any damage to the galvanizing shall be repaired in accordance with the requirements of Section 233 of the Specifications.

3.4 Connection Devices

Connection devices, such as bars, pins, plates etc, shall consist of non-degrading polymer or galvanized steel and be made for the express use with the segmental concrete blocks supplied.

3.5 Select Backfill Material

Select backfill material used in the reinforced zone shall be reasonably free from organic material, shale or other poor durability particles and otherwise deleterious materials. The backfill shall conform

to the following grading as determined by AASHTO T-27:

Sieve Size	Percent Passing
4 in.+	100
No. 40	0 - 60
No. 200	0 - 15

+ The maximum soil particle size for polymeric geogrid reinforcement shall be 3/4 inch unless full scale installation damage tests are conducted in accordance with ASTM D5818.

The Plasticity Index (P.I.) of the backfill material as determined by AASHTO T-90 shall not exceed 6.

Backfill material shall exhibit an angle of internal friction of not less than 34 degrees, as determined by the standard Direct Shear Test, AASHTO T236, on the portion finer than the #10 sieve, using a sample of the material compacted to 95 percent of AASHTO T99, Methods C or D, with oversized correction as outlined in Note 7, at optimum moisture content. No testing is required for material where 80 percent of sizes are greater than 3/4 inch.

Backfill material shall have a magnesium sulfate soundness loss of less than 30 percent after four cycles.

Additionally, the backfill material shall conform to the following electrochemical requirements:

- For metallic soil reinforcements:

Requirements	AASHTO Test Methods
a) pH range between 5.0 and 10.0	T289
b) Resistivity greater than 3,000 ohm-cm	T288
c) Chlorides less than 100 ppm	T291
d) Sulfates less than 200 ppm	T290
e) Organic Content less than 1%	T267

If resistivity is greater or equal to 5000 ohm-cm, the chlorides and sulfates requirements may be waived.

- For geosynthetic soil reinforcements:

Polyolefin Polymer (Polypropylene and High Density Polyethylene):

Requirement	AASHTO Test Methods
a) pH range between 3.0 and 11.0	T289

Polyester polymer:

Requirement	AASHTO Test Methods
a) pH range between 3.0 and 9.0	T289

The Contractor shall perform analysis tests for each source of material and shall perform such additional tests to assure conformance whenever the character of the select backfill material changes. All tests shall be performed by laboratories that are AASHTO Materials Reference Laboratory (AMRL) accredited.

The Contractor shall furnish the Engineer a Certificate of Compliance certifying the furnished select backfill materials comply with the aforementioned requirements. Test results performed by the Contractor necessary to assure contract compliance shall also be furnished the Engineer.

3.6 Block Unit Fill

Well graded crushed stone or crushed gravel placed in the segmental block voids (where required by wall manufacturer), between the blocks, and used as drainage aggregates behind the blocks shall meet the following gradation:

Sieve Size	Percent Passing
1-1/2 in.	100
1 in.	100 -75
¾ in.	50 -75
No. 4	0 - 60
No. 40	0 - 50
No. 200	0 - 5

3.7 Geotextile Filter Fabric

If required, separate the select backfill and block unit fill with a geotextile meeting the requirements for drainage fabric as specified in Section 245.03(c). The minimum lap shall be 12 inches.

3.8 Cast-In-Place Concrete

Concrete for leveling pads shall be Class B2 conforming to the requirements of Section 217 of the Specifications. All other cast-in-place concrete shall be Class A3 conforming to the requirements of Section 217 of the Specifications.

3.9 Cap Block Adhesive

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

4.0 CONSTRUCTION REQUIREMENTS

4.1 Wall Excavation

Wall excavation shall be unclassified in accordance with the requirements of Sections 506 and 401 of the Specifications and shall be performed in reasonably close conformity to the limits and construction stages shown on the plans.

4.2 Foundation Preparation

The foundation for the structure shall be graded level for a width equal to or exceeding the length of reinforcement or as shown on the Plans. Prior to wall construction, the foundation shall be compacted in accordance with the embankment requirements of Section 303.04 (h) of the Specifications and graded to a relatively smooth and uniform surface. Any foundation soils found to be unsuitable shall be removed and replaced with select backfill as per Materials of these specifications.

At each wall foundation level, an unreinforced concrete leveling pad shall be provided as shown on the plans. Leveling pads shall be level within 1/8 inch per pad or per 100 feet, whichever is greater. The pad shall be cured a minimum of 24 hours before placement of segmental blocks.

4.3 Block Installation

First course of segmental blocks shall be placed on leveling pad and leveled side-by-side and front-to-rear with adjacent blocks. Prior to placing the next course of blocks, all voids in and around the blocks shall be filled with unit fill. Drainage aggregate and select backfill shall be placed and compacted as shown on the plans. All excess materials shall be swept from the top of the blocks prior to installing the soil reinforcement and/or the next course of blocks. Blocks shall be installed in a running bond pattern and the method of aligning blocks shall follow block manufacturer's recommendations.

Successive courses shall be placed in the sequence and alignment shown on the plans as backfill proceeds. Wall facing vertical tolerances and horizontal alignment tolerances shall not exceed 0.75 inch when measured with a 10 feet straight edge. The overall vertical tolerance of wall (plumbness from top to bottom) shall not exceed 1-1/4 inch per 10 feet of wall height.

4.4 Soil Reinforcement Placement

Soil reinforcement shall be placed in accordance with the manufacturer's recommendations and these specifications. Soil reinforcement shall be placed within the layers of the compacted backfill material at the locations shown on the plans. Soil reinforcement shall be placed with the strongest direction of soil reinforcement perpendicular to the wall face, unless shown otherwise in the wall plan. Soil reinforcement shall be connected to the segmental block face in accordance with the block supplier's recommendations. The soil reinforcement shall then be laid flat and uniformly tensioned to remove any slack in the connection and soil reinforcement material.

4.5 Select Backfill Placement

The placement of the select backfill material shall closely follow the erection of each course of blocks. At each reinforcing element level, backfill shall be roughly leveled to an elevation approximately 1 inch above the level blocks before placing and attaching reinforcement to the blocks. Unless otherwise shown on the plans, reinforcement shall be placed normal to the face of the wall. The maximum lift thickness shall not exceed 8 inches loose and shall closely follow block installation. The Contractor shall decrease this lift thickness if necessary to obtain the specified density.

Backfill shall be compacted to 95% of the maximum density as determined by AASHTO T-99, Method C or D with oversize correction as outlined in Note 7. For backfills containing more than 80 percent material retained on the 3/4 inch sieve, a method of compaction consisting of at least four passes with a heavy roller shall be used. For applications where spread footings are used to support bridge or other structural loads, the top 5 feet below the footing elevation shall be compacted to 100 percent AASHTO T-99. The moisture content of the backfill material prior to and during compaction shall be uniformly distributed throughout each layer. Backfill material shall have a placement moisture content equal to the optimum moisture content. Moisture content may be up to 2 percentage points less than optimum moisture content.

Prior to placement of any backfill, geogrid shall be pulled taut to remove slack. The backfill shall be placed in a manner that geogrid remains taut. Tracked construction equipment shall not operate directly on geogrid. A minimum fill thickness of 6 inches over the geogrid is required prior to operation of tracked vehicles. Rubber tired equipment may pass over the geogrid at speeds less than 10 mph. Sudden braking and sharp turning shall be avoided.

At the end of each day's operations, the Contractor shall shape the last level of backfill as to permit runoff of rainwater away from the wall face. Backfill compaction shall be accomplished without disturbance or distortion of reinforcing elements and blocks. Compaction adjacent to the backside of the wall in a strip 3 feet wide shall be achieved using mechanical hand tampers.

4.6 Cast-In-Place Concrete

Concrete work for leveling pads and wall top coping shall be performed in accordance with the requirements of Section 404 of the Specifications.

5.0 MEASUREMENT AND PAYMENT

The quantity of Mechanically Stabilized Earth Walls (Segmental Block Facing) to be paid for will be the plan quantity, in units of square feet of retaining structure, as shown on the contract drawings. Unless otherwise defined on the plans, payment shall be full compensation for all excavation; temporary shoring when not specified on the wall plans or in the proposal as a separate pay item; concrete leveling pads; concrete segmental blocks; soil reinforcement; moment slabs; masonry; reinforcing steel; select backfill material; block unit fill, backfilling; compaction; geotextile filter fabric; riprap to fill temporary excavation, including all work necessary outside the retainage area shown on the plans; disposal offsite or onsite, where permitted by the Engineer, of unsuitable or surplus material; and all materials, labor, tools, equipment, and incidentals necessary to complete the work.

Payment will be made under:

Pay Item	Pay Unit
Retaining Structure	Square foot

WALL SETTLEMENT MONITORING REQUIREMENTS

All retaining wall settlement shall be monitored.

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 by construction equipment.

As soon as the first row of panels/blocks/stem that is above the proposed ground line is installed, the elevation of each pin shall be surveyed and this measurement will serve as the “baseline” for future settlement readings. 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. The settlement monitoring frequency shall then be adjusted to once weekly and continue at this frequency until the required waiting period has been completed and the Geotechnical Engineer of Record evaluates the data and confirms that the rate of settlement has stabilized, the primary consolidation or elastic settlement is complete, and that the remaining long-term settlement will not exceed the allowable amount.

Survey readings shall be immediately provided 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 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 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.
2	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.
3	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

Case	Description of Settlement Cases	Level of Monitoring Required
3 (Cont.)		been reached. Additional readings shall be taken 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 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 plan.

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%	100%	

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.

The "waiting" period starts when the survey readings at the completion of the wall construction are obtained and shall continue until the required waiting period has been completed and the Geotechnical Engineer of Record reviews the data and confirms that the rate of settlement has stabilized, primary consolidation or elastic settlement is complete and that the remaining long-term settlement will not exceed the allowable amount.

Survey readings shall be taken bi-weekly during wall construction and weekly thereafter until the waiting period is complete.

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