Supplemental Technical Specification for

MECHANICALLY STABILIZED EARTH (MSE) WALLS

SCDOT Designation: SC-M-713-1 (01/24)

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FEDERAL HIGHWAY ADMINISTRATION

1.0 GENERAL

1.1 This Supplemental Technical Specification (STS) is considered part of the current version of the Standard Specifications for Highway Construction (Standard Specifications) and replaces all prior versions of the Section 713.

1.2 According to the AASHTO LRFD Bridge Design Specifications, 9th Edition, 2020, Mechanically Stabilized Earth (MSE) walls are "…systems, whose elements may be proprietary, employ either metallic (strip or grid type) or geosynthetics (geotextile, *geo*strip, or geogrid) tensile reinforcements in the soil mass, and a facing element which is vertical or near vertical."

2.0 DESCRIPTION

2.1 This work consists of the internal design, furnishing materials, and constructing MSE walls in accordance with this STS, the Wall Manufacturer's recommendations, and in conformance with the lines, grades, designs, and dimensions shown in the Plans.

2.2 Design details for MSE wall structures such as type of wall facing (e.g., precast concrete panel, modular concrete block facing, etc.), loading conditions, leveling pad requirements, temporary surcharge retaining walls, and details for appurtenances are shown in the Plans or specified herein.

2.3 MSE wall internal design includes supplying engineering calculations and preparing all Shop Plans. Furnishing materials includes all MSE wall components such as facing elements, leveling pad, soil reinforcement and attachment devices, MSE wall backfill, wall coping, and any other project specific materials such as structural frames or other materials needed to accommodate designing around obstructions in walls, drainage features, etc. MSE wall construction includes structural excavation including removal of any obstructions for the MSE wall, constructing the concrete leveling pad, erecting the wall facing, placing and compacting reinforced backfill, installing soil reinforcements, installing a drainage system, installing coping, and installing other project specific items as required by the Project Plans, Shop Plans, this STS, Special Provisions, Wall Manufacturer's recommendations, etc.

2.4 The following terms are used in this STS for identification of various entities for which the Contractor is fully responsible:

Term	Entity
Wall Manufacturer	The entity contractually retained by the Contractor or wall subcontractor to provide materials and construction support services for an accepted MSE wall system.
Wall Designer	The entity contractually retained by the Contractor or wall subcontractor to provide internal design of an accepted MSE wall system. The Wall Designer may be a representative of the Wall Manufacturer.

Wall Subcontractor	Contractor or subcontractor providing construction services for an accepted MSE wall system.

2.5 Provide the Wall Designer with a complete set of Project Plans and Specifications and ensure that the wall design is compatible with all other project features that can impact the design and construction of the wall. The Wall Subcontractor shall provide a field representative who, in the past 3 years, has successfully installed at least 4 MSE walls of heights, lengths and complexity similar to those shown in the Plans and meeting the tolerances specified. Submit Wall Subcontractor's installation qualifications to the Resident Construction Engineer (RCE) at least 30 calendar days prior to MSE Wall construction. The Wall Subcontractor's field representative in coordination with the Wall Designer may make field changes subject to the approval of the RCE. Internal design and long term durability of all materials remain the responsibility of the Contractor. Provide documentation of all changes in writing within 24 hours of the approved changes. Ensure that this written document bears the legible seal, date, and signature of the responsible civil engineer registered as a Professional Engineer in the State of South Carolina, who is representing the Wall Designer. Any changes to the external design (i.e., changes in layout, height or location, etc.) will be reviewed and either accepted or rejected by the RCE. Allow 30 calendar days for this review and acceptance of proposed changes to the external design.

3.0 MSE WALL DESIGN

3.1 **Scope of Design:** MSE wall structures are considered flexible gravity walls. The Department will be responsible for evaluating the external stability of MSE wall structures, which consists of checking the global stability for deep-seated failures, sliding stability, eccentricity, settlement analysis, and bearing capacity. The external stability of the MSE wall structure is satisfied with the minimum base width required, B_{Req} that is specified in the Plans. For MSE walls used as temporary shoring see SC-M-204-2 – Temporary Shoring.

3.2 **Design Methodology:** The Contractor and the Wall Designer are responsible for both the internal and compound slope stability designs of MSE wall structures [see the Geotechnical Design Manual (GDM) for an explanation of compound slopes]. Determine the required soil reinforcement length and strength, facing/soil reinforcement connection strength, and facing stability in accordance with the Plans and this STS. The Contractor and the Wall Designer are responsible for the design of MSE wall facings and facing connections required during either standard MSE wall construction or during multi-stage MSE wall construction, and for other project specific requirements (wall drainage systems, designs that allow obstructions within the reinforced soil mass, etc.) that are required to build the MSE wall structure. Ensure that the project specific design criteria provided in the Plans are used in developing the MSE wall design. If design criteria are not shown in the Plans, follow the design procedure contained in the GDM. Do not allow the MSE wall factored bearing pressures to exceed the bearing capacities provided in the Plans. Prepare the Shop Plans using the MSE Wall Details provided in the Plans, including any details specific to the selected MSE Wall Manufacturer. Specify, on the Shop Plans, the minimum required wall face batter that is needed to build the wall to the required construction tolerances. Designs based on a methodology other than that required by this STS will not be accepted.

3.3 Maximum reinforcement loads shall be calculated using the "Simplified Method" as presented in AASHTO. No other design method will be allowed.

3.4 In addition, the following specific design requirements apply:

- Design, detail, and show required base drains and back drains to collect and remove groundwater before it can enter the reinforced backfill of the MSE wall, if the drains are required on the plans.
- For internal stability calculations, use acceleration values shown in the Plans for the Extreme Event I limit state check.
- Provide a reinforcement coverage ratio of 1.0 for all continuous reinforcement layers such as sheet type reinforcement (e.g., geogrid).
- With the exception of the top 2 layers of reinforcement, provide a constant length of all reinforcement layers within a design section to form a uniform reinforced soil mass. Provide the top 2 layers of reinforcement with a length of reinforcement that is 5 feet longer than all other layers below. This is an attempt to reduce the potential for tension cracks to develop directly above and behind the reinforced zone.
- Ensure that any temporary MSE walls used for staging or retaining surcharges and that interface with the reinforced backfill of a MSE wall are designed and detailed by the same Wall Designer and Wall Manufacturer responsible for the design of the MSE wall.
- Fully document the determination of all loading conditions and assumptions. Include in the calculations all load cases that exist during construction and at the end of construction for any surcharges, hydraulic conditions, live loads, combinations, and obstructions within the reinforced backfill.

3.5 Furnish verification for computer generated designs that ensure the computer program's design methodology meets the requirements provided in the SCDOT GDM and this STS as applicable.

3.6 Provide hand calculations for any special designs where computer models do not adequately capture the behavior of the structure. Provide in the design calculations a summary of the design computations that include design section identification, location, wall geometry (height, backslope, etc.), loadings (traffic loading, hydrostatic, seismic, traffic barrier, etc.), governing design resistance factors and elevation where they occur, and any other pertinent information.

4.0 MSE WALL SUBMITTALS, REVIEW, AND ACCEPTANCE

4.1 Submit design calculations and Shop Plans for review in accordance with the requirements provided in Section 725 of the Standard Specifications. Submit the design calculations and Shop Plans a minimum of 30 calendar days before the proposed date to start wall construction. All Shop Plan drawings shall conform to the latest edition of the SCDOT CADD Standards specifically the Bridge Design Files. The CADD Standards may be found on the SCDOT website.

4.2 Acceptance of the MSE wall design will be based on a review of the design calculations and the Shop Plans for conformance with the Plans, Specifications, this STS and SCDOT standard design practices. Ensure that all calculations and Shop Plans bear the legible seal, date, and signature of the responsible civil engineer registered as a Professional Engineer in the State of South Carolina. The Contractor, the Wall Manufacturer, and the Wall Designer are solely responsible for the accuracy, completeness, and constructability of the submitted design before and after review. Do not begin fabrication of the MSE wall components until written acceptance of the design and Shop Plans is provided. Review and acceptance will be in accordance with SCDOT Shop Plan review process.

4.3 If the Contractor or the Wall Manufacturer is required to supplement or revise the design submittal in order to obtain acceptance of the MSE wall design or MSE wall Certification Package,

the time allowances for acceptance may increase. No additional contract time will be given for any subsequent loss of construction time due to time delays caused by revisions, modifications, clarifications, or re-submittal of calculations or Shop Plans, or MSE wall Certification documentation that are not in conformance with the Plans and Specifications.

4.4 Include the following information on the Shop Plans:

- Final pay quantities based on verified ground elevations;
- Horizontal and vertical alignment of each wall;
- Elevation sheet(s) for each wall;
- Existing ground elevations that have been verified by the Contractor for each location;
- Proposed ground lines;
- Vertical bearing pressure exerted by the MSE wall structure relative to changes in wall height and soil reinforcement length;
- MSE wall profile elevation showing top of the leveling pad elevations, maximum bearing loads, top of wall elevation at a maximum interval of 25 feet, and at all slope changes, etc.;
- Typical cross-section(s) showing the elevation relationship between ground conditions and proposed grades;
- General notes pertaining to design criteria and wall construction;
- Details of slip joints if required to prevent stresses due to anticipated settlement or at interfaces with other structures;
- Details of all joints indicating type, size, and manufacturer;
- Details of wall batter; have the Wall Designer determine the required backward batter and adjust during construction as needed to build the wall to the required construction tolerances. A negative slope or batter (sloping outward of the face) will not be acceptable regardless of the wall tolerance achieved.
- Shape, dimensions, and any structural design details of MSE wall facings;
- Details of the architectural or finish treatment supplied;
- Details of facing/reinforcement connections;
- The number, size, type, length, and details of the soil reinforcing elements in each design section;
- Details showing location and installation of geotextile fabric;
- Details of the leveling pad showing dimensions;
- Finishing details at the top of wall (e.g., panel coping, barrier, pavements);
- Details at miscellaneous obstructions (e.g., drainage structures, utility conduits, pipes) located within the reinforced backfill;
- Details at bridge foundation obstructions (including foundations to be installed with the current project);
- Details of internal drainage system required by the Wall Designer, or as required by the Plans;
- Limits of structure excavation;
- Dimensions of reinforced backfill required;
- Required backfill material properties;
- Reinforcing steel schedule and bending details;
- Any assumptions beyond those provided by SCDOT; and
- Any additional details pertaining to coping, railing, temporary facing, and internal drainage, as required by the Plans.

4.5 **Shop Plan Notes:** Ensure that notes shown in the Shop Plans do not conflict with SCDOT Standard Specifications, Project Specifications, Special Provisions, and standard practice unless the notes are more stringent.

4.6 **Top of Wall Elevation:** Obtain written approval from the RCE to lower the top of wall elevations from that shown on the Plans. Ensure the top of the wall elevations allow for proper interfacing with barriers, copings, surface ditches, bridge abutments, etc. as shown in the Plans.

4.7 **Leveling Pad:** Obtain written approval from the RCE to raise or lower the leveling pad elevations shown in the Plans. Ensure that the leveling pad elevations allow for the transverse and longitudinal drainage structures shown in the Plans. Detail all top of leveling pads the lower of: 2 feet below the finished grade at the wall face; below the Extreme Event II scour elevation (3 feet min.) for streams adjacent to the wall face; or 2 feet below the bottom of any drainage features, utilities, or other structures adjacent to the wall face for future maintenance operations. Increase the minimum embedment depth if necessary due to bearing capacity, settlement, stability, erosion, or scour, and if utilities, ditches, or other structures are located adjacent to the wall. Make certain that the minimum embedment depths also meet the requirements shown below. These requirements are based on local bearing capacity considerations taking into account the geometry in front of the wall.

Table 1, Minimum MSE Wall Embedment Depth Based on Local Bearing Capacity

Slope in Front of Wall	Minimum Embedment Depth (feet)
Horizontal or slopes flatter than 3H:1V (walls)	Wall Height/20
Horizontal or slopes flatter than 3H:1V (abutments)	Wall Height /10
3H:1V	Wall Height /10
2H:1V	Wall Height /7
1.5H:1V	Wall Height /5

4.8 **Wall Interface and Vertical Joint Details:** Where an MSE wall interfaces with another wall (MSE wall, concrete barrier wall, wing wall, etc.); ensure that the Shop Plans contain slip joint details, special facing element details, details on how to end the wall or walls, and how to compact the embankment at these locations. Do not place the end of any MSE wall over any non-yielding foundations. All vertical joint lines shall be detailed in a manner to ensure that, for the life of the structure, the reinforced backfill does not migrate outside of the MSE wall system and the vertical joint is not wider than 1 inch. At locations where an MSE wall makes a 90 degree turn, use corner elements or corner blocks to make the turns. Show a detailed soil reinforcement layout where walls intersect (e.g., permanent MSE wall intersects a temporary MSE wall at 90 degrees or less).

4.9 **Earth Surcharges:** If the Plans indicate an earth surcharge is to be placed over the reinforced zone, the surcharge may be retained by using a temporary MSE wall structure. If a multi-stage wall construction method is being used, construct the surcharge as part of the first stage (temporary face) of the permanent wall and adjust as indicated in the Plans or as directed by the RCE.

4.10 **Precast Concrete Panel Facing Layout:** For MSE walls with precast concrete panel facing, provide a numbered panel layout drawing for fabrication and erection purposes.

5.0 MATERIALS

5.1 **MSE Wall Facings:** Purchase or manufacture all applicable materials such as facing panel, facing block, connectors, facing aggregate, block fill, welded wire mesh baskets, and all other necessary components and install as per project requirements.

5.2 **Precast Concrete Panel Facing**

5.2.1 Provide precast concrete panels that are designed in accordance with Section 5 of the AASHTO LRFD Bridge Design Specifications, with the exceptions and additions listed in Subsections 5.2.1.1 through 5.2.1.10, herein.

5.2.1.1 Size: Provide precast concrete panels that have a maximum width (w) to height (h) ratio, that is less than or equal to 1.20 (i.e., $w/h \leq 1.20$) and that have a maximum height (h) to width (w) ratio, that is less than or equal to 1.20 (i.e., $h/w \leq 1.20$). Ensure that the maximum surface area of the panel does not exceed 30 square feet. The ratios do not apply to the top and bottom rows nor at columns adjacent to slip joints or bends in the wall where smaller panels may be used.

5.2.1.2 Reinforcing Steel: Provide reinforcing steel that meets the requirements of Section 703 of the Standard Specifications. Fabricate and place reinforcing steel that conforms to the applicable requirements of Section 703. Submit a manufacturer's certification to the RCE that the reinforcing steel used in the facing panels is in conformance with this specification.

5.2.1.3 Concrete: Make certain that concrete and admixtures meet the requirements of Section 701 of the Standard Specifications, except that a third party certification will be required from either ACPA or NPCA. Details of certification programs offered by American Concrete Pipe Association (ACPA) are found at www.concretepipe.org and National Precast Concrete Association (NPCA) at www.precast.org. Provide copies of certifications provided by either ACPA or NPCA, including copies of the most recent audit performed by the association providing the certification and the corrective action plan to correct any deficiencies noted in the audit. Provide concrete conforming to the requirements of Class 4000P with a minimum 28-day compressive strength of 4,000 psi. Concrete to be provided by a concrete supplier from QPL 28; however, precast supplier that owns a concrete batching plant is exempt from using a concrete supplier listed on QPL 28. Provide leveling pad concrete conforming to the requirements of Class 2500 with a minimum 28-day compressive strength of 2,500 psi.

5.2.1.4 Casting: Notify the State Materials Engineer (SME) at least 14 calendar days before the production of precast concrete panels. Cast the panels on a flat surface, with the front face of the panel facing downward and the back face of the panel facing upward. Provide minimum clearance between tie strip guide or other galvanized devices and face panel reinforcing steel. Place the concrete in each panel without interruption and consolidate 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 form. Fully support the units until the concrete reaches a minimum compressive strength of 1,000 psi. Cure the panels with burlap for 36 hours or steam cure. Keep the forms in place until they can be removed without damage to the panel. The panels may be shipped 3 days after casting and attainment of the required concrete compressive strength of 4,000 psi.

5.2.1.5 Compressive Strength: Acceptance of the precast concrete panels with respect to compressive strength will be determined on a lot basis. A lot is defined as either 40 panels or

a single day's production, whichever is less. Randomly sample the lot for compressive strength testing in accordance with ASTM C172 and test in accordance with AASHTO T22 while meeting the requirements of the third party certification. Perform any strength retesting and acceptance in accordance with Section 701 of the Standard Specifications. Reject panels represented by test cylinders that do not reach the above requirements. Submit testing results and a manufacturer's certification to the RCE that the concrete used in the wall panels is in conformance with these specifications.

5.2.1.6 Markings: Clearly scribe the date of manufacture, the production lot number, and the panel identification number on the rear face of each panel.

5.2.1.7 Finish: Unless otherwise indicated in the Plans or directed by the RCE, ensure that the concrete surfacing for the front face has a deep fractured fin finish in accordance with Standard Drawing 701-950-01. All MSE wall panels shall have a natural light gray color (similar to AMS-STD 36307, 36373 or 36492) unless otherwise noted in the Plans. Make certain all concrete finishes conform to the requirements of Section 702 of the Standard Specifications. Provide the rear face with a uniform surface finish. Ensure that the rear face of the panel is roughly screeded to eliminate open pockets of aggregate and surface distortions in excess of 1/4 inch.

5.2.1.8 Tolerances: Manufacture precast concrete panels within the following tolerances:

- Panel Dimensions: Position panel connection devices to within 1 inch of the specified dimension. Ensure that all other dimensions are within 3/16 inch of the specified dimension.
- Panel Squareness: Ensure that the difference between the two diagonals does not exceed 1/2 inch.
- Panel Surface Finish: Ensure that surface defects on smooth formed surfaces measured over a length of 5 feet does not exceed 1/8 inch. Ensure that surface defects on the textured-finish surfaces measured over a length of 5 feet does not exceed 5/16 inch.

5.2.1.9 Rejection: Panels will be rejected because of failure to meet any of the requirements specified above. In addition, any of the following defects are sufficient cause for rejection:

- Defects that indicate imperfect molding.
- Defects indicating honeycomb or open texture concrete.
- Cracked or severely chipped panels.
- Color variation on front face of panel due to excess form oil or other reasons.
- Defective or damaged reinforcement connection devices.

5.2.1.10 Handling, Storage and Shipping: Handle, store, and ship panels in such a manner as to eliminate the dangers of chipping, discoloration, cracks, fractures, and excessive bending stresses. Support panels in storage on firm blocking located immediately adjacent to tie strips to avoid bending the tie strips.

5.2.2 **Panel Joint Material**

5.2.2.1 Install bearing pads of the dimensions and thickness shown in the Plans or the accepted Shop Plans. Ensure that bearing pads placed in horizontal joints between panels are preformed Ethylene Propylene Diene Monomer (EPDM) rubber pads. Supply a manufacturer's certification to the RCE that the bearing pad material conforms to ASTM D2000 Grade 2, Type A, Class A with a minimum Durometer Hardness of 60±5, or High Density Polyethylene (HDPE) pads with a minimum density of 0.946 g/cm^3 in accordance with ASTM D1505.

5.2.2.2 Determine the stiffness (axial and lateral), size, and number of bearing pads such that the final joint opening shall be 3/4 ± 1/4 inch. Ensure the Wall Designer submits substantiating calculations verifying the stiffness (axial and lateral), size, and numbering of bearing pads assuming, as a minimum, a vertical loading at a given joint equal to 2 times the weight of facing panels directly above that level. As part of the substantiating calculations, have the Wall Designer submit results of certified laboratory tests in the form of vertical load-vertical strain and vertical load-lateral strain curves for the specific bearing pads proposed by the Wall Designer. The vertical load-vertical strain curve should extend beyond the first yield point of the proposed bearing pad.

5.2.2.3 Cover all joints between panels on the back side of the wall with a geotextile meeting the requirements of SC-M-203-1 (high survivability). Install the fabric cover in accordance with Subsection 7.5.

5.2.3 **Panel Coping**

5.2.3.1 Place a cast-in-place or precast concrete cap over the upper most level of the precast concrete panels as detailed in the Plans. For cast-in-place coping, use Class 4000 concrete conforming to the requirements of Section 701 of the Standard Specifications. For precast concrete coping, use Class 4000P concrete conforming to the requirements of Section 701. If necessary, place concrete to level up the top row of MSE wall precast concrete panel facings prior to placing panel coping. Ensure the bottom of the coping is parallel to the finished grade and projects low enough to fully cover the stepped joint line between the leveling concrete and the top of the wall facing elements. For leveling concrete below precast concrete coping, use Class 3000 concrete conforming to the requirements of Section 701. Provide reinforcing steel that meets the requirements of Section 703 of the Standard Specifications. Fabricate and place reinforcing steel that conforms to the applicable requirements of Section 703. Submit a manufacturer's certification to the RCE that the concrete and reinforcing steel used in the panel coping are in conformance with these specifications. Locate all expansion and contraction joints to coincide with panel joints.

5.3 **Modular Concrete Block Facings**

5.3.1 Submit a manufacturer's certification to the RCE that the modular concrete blocks for each lot shipped are in conformance with this STS. For each particular lot shipped, ensure that the certification for each shipment lists the date manufactured, type of block, the average compressive strength, and the water absorption.

5.3.1.1 Concrete: Use Portland Cement Concrete with a minimum 28 day compressive strength of 4,000 psi. Limit maximum water absorption to 5% in accordance with ASTM C140. Ensure that admixtures conform to the requirements in Section 701 of the Standard Specifications.

5.3.1.2 Casting: Cast the modular concrete blocks in steel molds and in a manner that will ensure the production of uniform modular concrete blocks. Place the concrete in each block without interruption and consolidate. Make certain the blocks reach a minimum compressive strength of 4,000 psi before being shipped.

5.3.1.3 Compressive Strength: Acceptance of the modular concrete blocks with respect to compressive strength is determined on a per lot basis with a lot being defined as a single day's production. Randomly sample the lot in accordance with ASTM C140. Have the Wall Manufacturer prepare and perform compressive strength tests on test specimens. Ensure that the compressive strength test specimens conform to the saw-cut coupon provisions of ASTM C140. Block lots will be approved when the average compressive strength is 4,000 psi of 3 test coupons and with no individual test having a compressive strength less than 3,500 psi. Block lots not reaching the above requirements will be rejected.

5.3.1.4 Markings: Clearly mark on each lot the date of manufacture, lot number, and type of block in accordance with the approved MSE wall Shop plans.

5.3.1.5 Finish: Unless otherwise indicated in the Plans or directed by the RCE, provide on the front face of the blocks a natural gray (similar to AMS-STD 36307, 36373 or 36492) color roughened surface (granite) finish in accordance with Standard Drawing 701-950-01.

5.3.1.6 Tolerances: Provide modular concrete blocks manufactured within the following tolerances:

- Ensure that the length and width of each individual block is within 1/8 inch of the specified dimension.
- Ensure that hollow units have a minimum wall thickness of 1-1/4 inch.
- Ensure that the height of each individual block is within 1/16 inch of the specified dimension.
- Ensure that the horizontal dimension of the front face is within 1 inch of the theoretical dimension of the individual block shown in the Plans.

5.3.1.7 Rejection: Modular concrete blocks will be rejected 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 indicating honeycomb or open texture concrete.
- Cracks greater than 0.02 inches in width and longer than 25 percent of the height of the block.
- Severely chipped or broken blocks.
- Color variation on front face of block due to excess form oil or other reasons.
- Defective or damaged reinforcement connection devices built into the modular concrete block.

5.3.1.8 Handling, Storage and Shipping: Handle, store, and ship modular concrete blocks in such a manner as to eliminate the dangers of chipping, discoloration, cracks, or fractures.

5.3.1.9 Block Fill: Furnish block fill in accordance with Subsection 5.5.4 when modular concrete blocks require a block fill for connection strength or when vertical void spaces exist within the modular concrete block.

5.3.1.10 Free Draining Aggregate: Provide a 12-inch thick free draining aggregate layer in accordance with Subsection 5.5.5. When a granular backfill is used with modular concrete block facings, use a geotextile fabric meeting the requirements of SC-M-203-1 (moderate survivability). In addition to the 12-inch aggregate layer, fill any void spaces along the backside of the modular concrete blocks with the same aggregate.

5.3.2 **Block Coping**

5.3.2.1 Place a cast-in-place concrete coping over the upper most level of modular concrete blocks as indicated in the Plans or as shown on the accepted Shop Plans. Provide Class 4000 concrete conforming to Section 701 of the Standard Specifications. Use reinforcing steel that meets the requirements of Section 703 of the Standard Specifications. Fabricate and place reinforcing steel that conforms to the requirements of Section 703. Submit a manufacturer's certification to the RCE that the concrete and reinforcing steel used in the block coping are in conformance with these specifications.

5.4 MSE Wall Temporary Facing

5.4.1 **Welded Wire Mesh Facing:** Furnish reinforcing mesh that is shop-fabricated of cold drawn steel wire from a welded wire manufacturer. Supply a manufacturer's certification to the RCE that the material conforms to the requirements of AASHTO M336, has been welded into the finished mesh fabric in accordance with the requirements of AASHTO M336. Alternatively, welded wire may also be obtained from a supplier listed on QPL 85.Conform galvanization to the minimum requirements of AASHTO M111. For 2-stage MSE Walls apply a minimum of 2.0 oz/sq.ft. or achieve 3.4 mils of galvanization to all surfaces of the mesh after the mesh is fabricated. For temporary MSE Wall applications black steel may be used; however, if the temporary MSE Wall is to be exposed for more than 5 years, galvanized welded wire similar to the 2-stage MSE Wall application is required.

5.4.2 **Temporary Facing Drainage Fabric:** Provide the temporary geotextile drainage fabric as detailed in the Plans. Use geotextile fabric meeting the requirements of SC-M-203-1 (high survivability).

5.5 Reinforced Backfill Material

5.5.1 **General:** Provide either granular or stone backfill for the reinforced backfill material for MSE walls. Use material free of shale, organic matter, mica, gypsum, smectite, montmorillonite, or other soft, poor durability particles. Use material free of salvaged material such as asphaltic concrete millings, Portland Cement Concrete rubble, etc. Ensure that the granular and stone backfills conform to Section 205 of the Standard Specifications with the engineering properties and material requirements in Subsections 5.5.2 through 5.5.7.

5.5.2 **Granular Backfill:** Use an internal friction angle (ϕ) of 32° for design of the MSE wall regardless of project specific testing. Use a granular backfill material with a gradation in accordance with Table 2. In addition, fine aggregates meeting SCDOT designations FA-10, FA-10M, FA-12 and FA-13 may also be used. These fine aggregates may be obtained from a source listed on *SCDOT Qualified Product List 1.*

Table 2, Reinforced Granular Backfill Gradation (AASHTO T 27 and T 88)

Sieve Size		Percent Passing
Inextensible Reinforcement (steel) = 1 ½"	37.5 mm	100
Extensible Reinforcement (geosynthetic) = ¾"[1]	19 mm	100[2]
3/8"	9.5 mm	-[3]
No. 4	4.75 mm	-[3]
No. 8	2.36 mm	-[3]
No.16	1.18 mm	-[3]
No. 30	0.60 mm	-[3]
No. 40	0.42 mm	0 – 60
No. 50	0.30 mm	-[3]
No. 100	0.15 mm	-[3]
No. 200	0.075 mm	0 – 15

[1]Maximum particle size may be increased to 1-1/2", provide installation damage tests performed using project specific backfill and extensible reinforcement materials
[2]For extensible reinforcement only otherwise see Note 3
[3]Sieve stack established per T 88; however, no percent passing established

5.5.3 **Stone Backfill:** Use an internal friction angle (ϕ) for the reinforced stone backfill of 38° and use an internal friction angel (ϕ) for screenings used as reinforced stone backfill of 36°. For stone backfill material, use a coarse aggregate in accordance with Table 3 and obtained from a source listed on *SCDOT Qualified Product List 2*. However, should the screenings from the production of stone backfill meet the requirements of Table 2, the screenings will be considered acceptable as stone backfill except as noted in the following subsections.

Table 3, Reinforced Stone Backfill

Soil Reinforcement Type	Coarse Aggregate (SCDOT Standard Specifications for Highway Construction, latest Edition)
Extensible Reinforcement (geosynthetic)	No. 67, No. 6M, 8M, 78, 789, 89M, Macadam[1]
Inextensible Reinforcement (steel)	CR-14, No. 5, No. 56, No. 57, No. 67, No. 6M, 8M, 78, 789, 89M, Macadam[1]

[1]Macadam is not permitted if wall can be inundated with water (see Plans)

5.5.4 **Block Fill:** When the MSE Wall system requires block fill use coarse aggregate No. 67; No. 6M, or No. 789 obtained from a source listed on *SCDOT Qualified Product List 2*.

5.5.5 **Free Draining Aggregate:** Use coarse aggregate No. 67; No. 6M, or No. 789 obtained from a source listed on *SCDOT Qualified Product List 2*.

5.5.6 **Reinforced Backfill Property Requirements**: Ensure that all reinforced backfill (granular or stone), block fill, and free draining aggregate have the following soil properties:

- pH values between 5.0 and 10.0 for metallic reinforcements, pH values between 3.0 and 9.0 for polyester reinforcements, and pH values greater than 3.0 for polypropylene and high density polyethylene (HDPE) reinforcements.
    - For granular backfill, determine pH values in accordance with AASHTO T 289.

    - For stone backfill and screenings, prepare sample as follows: Obtain approximately 2-1/2 pounds of representative material. Transfer the sample into a 1 gallon wide mouth plastic jug. Add an equal weight of deionized or distilled water to the sample and let the mixture sit for approximately 30 minutes. At the end of this period, place a lid on the container and vigorously agitate the mixture for 3 minutes. Repeat agitation 2 hours after the initial agitation and again 4 hours after the initial agitation. After the agitation at the 4-hour time interval, allow the sample to sit for approximately 20 hours to allow for any solids to settle out. After the sample sits for 20 hours, remove a sufficient amount of the solution and filter through a coarse paper (such as Fisher Q8) to obtain the supernate to be analyzed. Analyze the supernate according to ASTM D1293 (pH).
    - Determine pH of block fill and free draining aggregate using the same procedure as stone backfill.
- Organic content not to exceed 1.0 percent (weight of organic material to weight of total sample) as determined by AASHTO T267 for material finer than No. 10 sieve.
- Internal friction angle not less than the values specified in Subsections 5.5.2 as determined by the standard direct shear test (AASHTO T236) or the triaxial test (AASHTO T297) on the portion passing the No. 10 sieve. Compact material test samples to 95% (AASHTO T99, Method C or D) of maximum density at optimum moisture content.
- Internal friction angle testing of backfills meeting the requirements of Subsection 5.5.3 (Stone Backfill, including screenings) is not required.
- The reinforced backfill material shall have a soundness loss of 30 percent or less when tested in accordance with AASHTO T104 using magnesium sulfate solution with a test duration of 4 cycles. Alternatively, the material shall have a soundness loss of 15 percent or less when tested in accordance with AASHTO T104 using a sodium sulfate solution with a test duration of 5 cycles.
- Granular material and screenings used as reinforced backfill shall classify as well-graded in accordance with the Unified Soil Classification System (USCS) as described in ASTM D2487. However, a C_u greater than or equal to 4 may be used for granular backfill or screenings. The Coefficient of Uniformity, C_u, and the Coefficient of Curvature, C_c, must meet the criteria as follows:

$$4 \leq C_u < 20$$
$$1 \leq C_c \leq 3$$

Determine C_u and C_c using the following equations:

$$\boldsymbol{C_u = \frac{D_{60}}{D_{10}}} \qquad \textbf{Equation 1}$$

$$\boldsymbol{C_c = \frac{(D_{30})^2}{(D_{10}) * (D_{60})}} \qquad \textbf{Equation 2}$$

Where:

D_{60} = Particle diameter at 60 percent passing
D_{30} = Particle diameter at 30 percent passing
D_{10} = Particle diameter at 10 percent passing

- To prevent the reinforced backfill material, both granular and screenings, from being gap-graded, determine the slope between consecutive sieves that have less than or equal to 80 percent passing and have more than or equal to 20 percent passing. The slope of this segment shall not be less than 10 percent.
- (i.e., no horizontal line along the length of the gradation curve, SCDOT will make this determination).
- Plasticity Index (PI) less than or equal to 6 and the Liquid Limit (LL) less than or equal to 30 as determined by AASHTO T90. These limits are applicable to granular backfill and screenings only.
- When metallic soil reinforcements are used, the resistivity of the reinforced backfill fill shall be greater than or equal to 5,000 ohm-cm (AASHTO T288). Use the lowest resistivity prior to saturation or the resistivity at saturation as the resistivity of the granular backfill. For stone backfill, screenings, block fill and free draining aggregate, test the supernate developed using the method discussed previously using ASTM D1125. **Testing Frequency:** Test soil properties during initial source evaluation or for a change in source. Sample reinforced backfill material once every 2,000 cubic yards and test for gradation and pH. For walls with less than 2,000 cubic yards of reinforced backfill, sample and test a minimum of 2 samples for gradation and pH. Sample reinforced backfill material once every 15,000 cubic yards and test for internal friction angle, organic content, and resistivity. For walls with less than 15,000 cubic yards of reinforced backfill, sample and test a minimum of 2 samples for internal friction, organic content and resistivity. A variation in testing frequency may be required if a variation in material gradation or composition is observed.

5.6 **Soil Reinforcements and Attachment Devices**

5.6.1 Purchase or manufacture all applicable materials such as soil reinforcements, attachment devices, and all other necessary components.

5.6.2 **Inextensible Soil Reinforcement**

5.6.2.1 General: Ensure inextensible reinforcement conforms to the required shape and dimensions as indicated on the Shop Plans and is free of defects that may impair its strength and durability. Provide a mill test report to the RCE with each shipment. Submit a signed certification to the RCE that all inextensible soil reinforcement is in conformance with these specifications.

5.6.2.2 Reinforcing Steel Strips: Provide galvanized reinforcing strips that are hot rolled from bars to the required shape and dimensions. Ensure that their physical and mechanical properties conform to ASTM A572, Grade 65 minimum. Apply a minimum of either 2.0 oz/sq.ft. or achieve 3.4 mils of galvanization to all surfaces of the reinforcement. In addition, ensure that galvanization conforms to the requirements of AASHTO M111.

5.6.2.3 Metallic Reinforcing Mesh: Provide galvanized reinforcing mesh that is shop-fabricated of cold drawn steel wire from a welded wire manufacturer. Supply a manufacturer's certification indicating conformance to the requirements of AASHTO M336, and welded into the finish mesh fabric in accordance with AASHTO M336. Apply galvanization after the mesh is fabricated, and ensure that galvanization conforms to the requirements of AASHTO M111. Apply a minimum of either 2.0 oz/sq.ft. or achieve 3.4 mils of galvanization to all surfaces of the reinforcing mesh.

5.6.2.4 Bar Mats: Fabricate bar mats from AASHTO M270, Grade 50 steel. Apply galvanization after the bar mats and connector pins have been welded. Ensure that galvanization conforms to the requirements of AASHTO M111 or M232 as applicable. Apply a minimum of either 2.0 oz/sq.ft. or achieve 3.4 mils of galvanization to all surfaces of the reinforcement.

5.6.2.5 **Galvanization Damage:** Repair damage done to the galvanization prior to the soil reinforcement installation in accordance with ASTM A780.

5.6.3 **Extensible Soil Reinforcement**

5.6.3.1 Ensure that reinforcing conforms to the required shape and dimensions and is free of defects that may impair its strength and durability.

5.6.3.2 Geosynthetic Soil Reinforcement: Use geosynthetic soil reinforcement meeting the design requirements shown in the Plans and specified in the Shop Plans. Geosynthetic reinforcement may consist of geotextiles, geogrids or geostrips. Ensure that geotextile reinforcement is a woven geotextile consisting only of long chain polymeric filaments or yarns formed into a stable network. Ensure that geogrid reinforcements are a regular network of integrally connected polymer tensile elements with aperture geometry sufficient to permit significant mechanical interlock with the surrounding backfill material. Ensure that geostrip reinforcement is a multifilament polyester yarn encased in an extruded polyethylene sheath to form a single geostrip. Provide geosynthetic reinforcements having a structure that is dimensionally stable and able to retain its geometry under construction stresses and that have high resistance to damage during construction, to ultraviolet degradation, and to all forms of chemical and biological degradation encountered in the soil being reinforced. Geotextile reinforcements shall meet the requirements of STS SC-M-203-3 and geogrid reinforcements shall meet the requirements of STS SC-M-203-2. When the geosynthetic reinforcement is comprised of geostrips, the geostrips shall meet the requirements indicated in the Table 4.

Table 4, Properties of Geostrip Polymeric Components

Property	Test Method	Unit	Grade		
Ultimate Tensile Strength	ASTM D 6637	lbf	8,400	11,240	14,600
Elongation @ Ultimate (average)		%	10		
Carboxyl End Group Count	ASTM D 7409	mmol/kg	<30		
Molecular Weight by Viscosity	ASTM D 4603	g/mol	>25,000		
Weight per 300-foot coil of finished geostrip (approximate)		lbs	22	28	37
Width (nominal – not to be measured for conformance)		inches	2 (+0, -1/8 inches)		
Thickness (nominal – not to be measured for conformance)		inches	3/16 (+/- 1/16 inches)		

5.6.3.3 Delivery, Storage, and Handling of Geosynthetic Materials: Check the geosynthetic soil reinforcement upon delivery to ensure that the proper material has been received. Make

certain that geosynthetic rolls are labeled per ASTM D4873. During all periods of shipment and storage, protect the geosynthetic materials from temperatures greater than 140°F, mud, dirt, dust, and debris. Follow the manufacturer's recommendations regarding protection from direct sunlight. At the time of installation, the geosynthetic material will be rejected if it has defects, tears, punctures, flaws, deterioration, or damage incurred during manufacturing, transportation, or storage. At no additional cost to the Department, replace any geotextile fabric or geosynthetic reinforcement damaged during storage or installation.

5.6.3.4 Manufacturing Quality Control: Submit to the RCE a manufacturing quality control certificate and conformance testing results for all geosynthetic soil reinforcement delivered to the site. Perform sampling and conformance testing in accordance with ASTM D4354. For all geosynthetic soil reinforcement, provide conformance testing of ultimate tensile strength, T_{ult}, in accordance with Subsection 5.7. Ensure that the quality control certificate includes roll numbers and identification, sampling procedures, and results of the conformance testing with a description of test methods used. Include a signed certification to the RCE that all extensible soil reinforcement is in conformance with these specifications with the submitted quality control certificate.

5.6.4 **Reinforcement Attachment Devices**

5.6.4.1 Make certain all reinforcing attachment devices conform to the required shape and dimensions and are free of defects that may impair their strength, durability, and functionality. Submit a manufacturer's certification to the RCE that the materials are in conformance with this specification.

5.6.4.2 Tie Strips: Provide tie strips that are shop fabricated of hot-rolled steel conforming to the requirements of ASTM A1011, Grade 50 minimum. Use a bending radius that is greater than or equal to 3/8 inch. Apply galvanization after the strips are fabricated, inclusive of punch holes for bolts. Apply a minimum of either 2.0 oz/sq.ft. or achieve 3.4 mils of galvanization to all surfaces of the strips and ensure galvanization conforms to the requirements of AASHTO M111.

5.6.4.3 Fasteners: Furnish connection hardware conforming to the requirements shown in the approved Shop Plans. Cast connection hardware in the precast concrete panels such that all connectors are in alignment and able to transfer full and even load to the soil reinforcement. Ensure fasteners consist of hexagonal cap screw bolts and nuts conforming to the requirements of ASTM F3125 or ASTM A449. Apply a minimum of either 2.0 oz/sq.ft. or achieve 3.4 mils of galvanization to all surfaces of the fasteners and ensure galvanization conforms to the requirements of AASHTO M232 or ASTM F2329.

5.6.4.4 Connector Pins: Fabricate connector pins from AASHTO M270, Grade 50, steel and weld to the soil reinforcement mats as shown on the Shop Plans. Fabricate connector bars from cold drawn steel wire conforming to the requirements of AASHTO M 336. Apply a minimum of either 2.0 oz/sq.ft. or achieve 3.4 mils of galvanization to all surfaces of the connector pins and/or bars and ensure galvanization conforms to the requirements of AASHTO M111.

5.6.4.5 Geostrip Insert: The geostrip insert shall be designed by the MSE Wall Supplier and shall be designed to carry the loads placed on the geostrip reinforcement. Cast the insert into the precast concrete panels such that all inserts are in alignment and able to transfer full and even load to the soil reinforcement. Inserts shall not interfere with the panel reinforcement. The inserts shall be fabricated from 100 percent virgin polyolefin and contain no more than 2

percent carbon black by weight. The inserts shall not cause corrosion or deterioration of either the concrete used to construct the panel or the reinforcement located in the panel.

5.6.4.6 Turn-Buckle Connectors: For permanent walls that are indicated in the Plans to be constructed using multi-stage construction methods, provide connection hardware conforming to the requirements shown in the approved Shop Plans. Determine the size and type of the turn-buckles and the number of connectors considering the facing panel size, distance between the 2 facing units, the type of infill used (if required), and the amount of relative settlement anticipated between the 2 facing systems after the second stage facing is constructed. Cast connection hardware in the precast concrete panels such that all connectors are in alignment and able to transfer full and even load to the soil reinforcement. Ensure fasteners consist of hexagonal cap screw bolts and nuts conforming to the requirements of ASTM F3125 or ASTM A449. Apply a minimum of either 2.0 oz/sq.ft. or achieve 3.4 mils of galvanization to all surfaces of the components of the turn-buckle connector and ensure galvanization conforms to the requirements of AASHTO M232.

5.7 **MSE Wall System Certification Package**

5.7.1 **General:** Include the certifications indicated in the preceding paragraphs in the MSE Wall System Certification Package. Submit the MSE Wall Certification Package to the RCE at least 45 calendar days prior to ordering materials for the MSE wall and allow at least 30 calendar days for review of the MSE Wall System Certification Package. This Certification Package is for the MSE wall system. Do not order any materials until the MSE Wall System Certification Package is approved. Items to be included, but not limited to concrete and reinforcement for concrete panels, concrete for modular blocks, bearing pads, etc. The following subsections include information required for soil reinforcements that are required to be included in the certification package.

5.7.2 **Geosynthetic Soil Reinforcements:** When geosynthetic soil reinforcements are used to construct MSE walls, submit to the RCE as part of the MSE Wall System Certification Package prepared by the Wall Manufacturer. A statement that the furnished geosynthetic and the connection between the geosynthetic and the wall facing meets the design requirements as stated on the approved Shop Plans. Perform any tests required at no additional cost to the Department and in conformance with the testing requirements found in FHWA-NHI-10-025, “Design and Construction of Mechanically Stabilized Earth Walls and Reinforced Soil Slopes – Volume II”, 2009. Use geosynthetic reinforcement that meets the requirements of STS SC-M-203-2 – *Geogrid Soil Reinforcement* or STS SC-M-203-3 – *Geotextile Soil Reinforcement.* Provide all documentation required in these STSs. If geostrips are used as the reinforcement, include in the certification package all of the information included in Table 4. In addition provide documentation indicating the strength reduction factors, CR_{CR} and RF_D, for the long-term connection strength between geosynthetic soil reinforcement and modular block facing.

5.7.2 **Metallic Soil Reinforcements:** When metallic soil reinforcements are used to construct MSE walls, submit to the RCE as part of the MSE Wall System Certification Package prepared by the Wall Manufacturer, the certified mill test report containing the ultimate tensile strength for the soil reinforcement. Also include a mill test report containing the galvanization coverage including amount applied and average thickness of galvanization. For metallic mesh wall reinforcement, include a mill test report containing the ultimate weld strength for the soil reinforcement.

5.8 **Miscellaneous Construction Materials**

5.8.1 **Leveling Pad:** Construct an unreinforced cast-in-place concrete leveling pad as shown in the Plans using Class 2500 concrete conforming to the applicable requirements of Section 701 of the Standard Specifications.

5.8.2 **Geotextile for Drainage Filtration:** Install geotextile for drainage filtration as shown in the Shop Plans. Provide a high survivability, nonwoven separation geotextile fabric that conforms to the requirements of STS SC-M-203-1 – *Geosynthetic Materials – Separation & Stabilization*. Submit to the RCE a manufacturer's certification that the geosynthetic material is in conformance with SC-M-203-1.

5.8.3 **Geomembrane:** Place a single-layer continuous polymeric sheet as specified in the Plans. Glue or weld all seams in the membrane to prevent leakage. Use a geomembrane manufactured from a virgin polymeric resin. Make certain the geomembrane conforms to the requirements shown in Table 5. Submit to the RCE a manufacturer's certification that the materials are in conformance with Table 5.

Table 5, Geomembrane Properties

Property	Test Method	Minimum Average Roll Value (MARV)
Thickness, mills	ASTM D5199	40
Tensile, lb/in	ASTM D882, 1 inch strip	70
Tear, lb	ASTM D1004, Die C	20
Puncture, lb	ASTM D4833	40
Impact, ft-lb	ASTM D1424	25

5.8.4 **Timber Spacer Block:** Use treated timber spacer block between concrete panel and precast coping as specified in the Plans. Timber spacer block shall conform to Section 706 and shall be treated (preserved) in accordance with Section 707 of the Standard Construction Specifications.

5.8.5 **Reflective Cracking Geogrid:** Use a B4 geogrid to prevent reflective cracking in the pavement above the junction of the reinforced backfill and the retained fill. See SC-M-203-2 for the property requirements for the B4 geogrid. Place the geogrid as indicated in the Plans.

5.8.6 **Expansion Joint Material:** Expansion Joint Material shall conform to the requirements of Section 702.2.2 of the Standard Construction Specifications at locations specified in the Plans.

6.0 EQUIPMENT

6.1 Ensure that the equipment necessary for the proper construction of the work is on site, is in acceptable working condition, and is acceptable to the RCE as to both type and condition before the start of work under this STS. Provide sufficient equipment to enable execution of the work in accordance with the project schedule and completion of the work in the specified time.

7.0 CONSTRUCTION

7.1 **Wall Excavation and Foundation Preparation:** Prepare wall excavation and foundation in accordance with Section 204 of the Standard Specifications. In addition to the requirements of

Section 204, proof roll the area where the MSE wall will be constructed with a minimum of 5 passes by pneumatic tire equipment weighing a minimum of 8 tons.

7.2 **Leveling Pad Construction:** At each MSE wall foundation level, provide a cast-in-place unreinforced concrete leveling pad as shown in the Plans. Cure the leveling pad a minimum of 12 hours before placement of wall facing panels or blocks. If the permanent MSE wall facing is to be installed in front of a temporary MSE wall facing, install the leveling pad just prior to construction of the permanent MSE wall facing. Construct top surface of leveling pad so it is level in both directions. Reject leveling pad when top surface deviates from level by more than 1/8 inch in 10 feet, except at designated steps in the leveling pad shown on the Plans or accepted Shop Plans.

7.3 **MSE Wall System Supplier's Assistance and Samples**

7.3.1 Have the Wall Manufacturer and Wall Designer provide qualified and experienced advisory personnel at the start of the wall construction and until such time that the RCE believes the SCDOT inspectors and the Contractor's personnel are adequately acquainted with the MSE wall construction procedures and no longer require technical assistance. Ensure that the representatives are also available on an as needed basis, as requested by the RCE, throughout the construction of the MSE wall structures.

7.3.2 Provide the RCE with 3 MSE wall field installation manuals, specific to the MSE wall type being constructed. If the MSE wall is reinforced with geosynthetics, provide the RCE with 2 sets of samples (approx. 1 square foot each) of each type of geosynthetic soil reinforcement that will be used. Ensure that each sample has a durable tag attached to it, stating the geosynthetic manufacturer and type/model.

7.4 **Internal Drainage System:** Install an internal drainage system behind the wall as indicated in the Plans and Shop Plans. Coordinate the internal drainage system with adjacent drainage features as needed to ensure positive drainage. Place outlet pipes at sags in the flow line, at the low end of the collector pipe, and at other locations as shown or specified. Determine the location and elevation of the internal drainage system and include the details in the Shop Plans. Form openings for weep holes in precast facing panels prior to casting the panels.

7.5 **Location of Geotextile for Drainage Filtration**

7.5.1 For MSE walls with precast concrete panel facings, provide a geotextile fabric covering all joints between panels on the backside of the wall, including the joint along the leveling pad. Make certain the geotextile fabric has a minimum width of 18 inches and overlaps adjacent geotextile fabrics a minimum of 4 inches. Adhere the geotextile fabric to the panels by applying adhesive to the back of the panel on each side of the joint. Do not apply adhesive directly on the geotextile fabric or within 2 inches of the panel joint edge.

7.5.2 For MSE walls with modular concrete block facings and granular reinforced backfill, place a geotextile between the free draining aggregate and the reinforced backfill. If a reinforced stone backfill is used, place the geotextile between the reinforced backfill and the retained backfill as shown in the Plans.

7.5.3 If required in the Plans, place geotextile fabric between the natural ground and the reinforced backfill. Ensure that the subgrade to receive the geotextile fabric is free of loose or extraneous material and sharp objects that may damage the geotextile fabric during installation.

Stretch, align, and place the geotextile fabric in a wrinkle-free manner and ensure that it has intimate contact with the soil. Overlap adjacent geotextile fabric edges a minimum of 1.5 feet.

7.5.4 At the direction of the RCE, repair or replace torn or punctured sections of the geotextile fabric. Cut out geotextile fabric damaged during installation and completely replace or repair by placing a piece of fabric that is large enough to cover the damaged area. Provide a sufficient overlap, 1.5 feet minimum, on all sides to secure the damaged geotextile fabric area.

7.6 **Wall Erection**

7.6.1 Place precast concrete panels and modular concrete block facings so that their final position is as shown in the Shop Plans. Place precast concrete panels and modular concrete block facings in successive horizontal lifts. Construct the MSE wall structure using a predetermined backward batter corresponding to the anticipated outward wall deflection due to the active soil pressures. This backward batter is shown on the Shop Plans; adjust the batter during construction as needed to build the wall to the required construction tolerances. Implement an installation method to avoid vertical wall alignment resulting in a negative slope or batter (sloping outward (i.e., away from the reinforced fill) from the perpendicular projection of the leveling pad).

7.6.2 Handle MSE wall precast concrete panels by a lifting device set into the upper edge of the panels or as indicated in the Shop Plans. Place the first level of precast concrete panels directly on the concrete leveling pad. Do not use horizontal joint material or wooden shims to adjust the height of the first course of panels and the leveling pad. Provide external bracing for the first lift of precast concrete panels. As backfill material is placed behind a panel, maintain the panel in position by means of temporary wooden wedges or bracing in accordance with the MSE Wall Manufacturer's recommendations. Remove the wooden wedges as soon as the panel above the wedged panel is completely erected and backfilled. Backfill in front of wall and above leveling pad to prevent erosion and to prevent water from ponding adjacent to leveling pad.

7.6.3 For walls that are indicated in the Plans to be constructed using multi-stage construction methods, use the following construction sequence:

- Install settlement monitoring instrumentation, if required, in accordance with the Plans prior to commencement of multi-stage MSE wall construction.
- Construct the MSE wall with temporary welded wire mesh facing as indicated in the Plans to allow for settlement to occur. Locate welded wire mesh facing to allow construction of the second stage of the permanent MSE wall facing.
- After the RCE in consultation with the GEOR has determined sufficient settlement has occurred, the Department will provide written notice to proceed with the construction of permanent facing.
- Construct the MSE wall leveling pad at the location of the permanent wall facing.
- Place the permanent wall facing and attach connections to the soil reinforcement as indicated in the MSE wall details included in the accepted Shop Plans.
- As the permanent facing is being placed, backfill the space between the temporary and the permanent facings, if required.
- Backfill in front of wall and above leveling pad to prevent erosion or ponding of water adjacent to leveling pad.

7.7 **Joint Material:** Install joint material to the dimensions and thickness shown in the Plans, or the accepted Shop Plans.

7.8 **Reinforced Backfill Placement**

7.8.1 Closely follow the erection of each lift of facing elements with the backfill placement. At each level of soil reinforcement, roughly level the backfill material to an elevation approximately 1-2 inches above the level of the connection at the facing before placing the soil reinforcement. Place backfill in such a manner as to avoid any damage or disturbance of the wall materials. Remove and replace, at the Contractor's expense, all wall materials that become damaged during backfill placement. Make certain that the backfill placement methods near the facing do not create voids directly beneath the reinforcing elements.

7.8.2 Place, spread and compact the reinforced backfill materials in successive uniform, horizontal layers. Compact granular, including screenings, backfill to meet the design requirements but not less to than 95.0 percent of the maximum dry density in accordance with AASHTO T99. Perform compaction control testing of the reinforced backfill with a minimum frequency of 1 density test per every 2 lifts for every 25 feet of wall at bridge abutments (any portion of wall within 150 feet of a bridge) and every 100 feet of wall along roadways (more than 150 feet away from a bridge).

7.8.3 Compact stone backfill material with a minimum of 4 passes with a smooth heavy roller (approximately 15 tons). Compaction testing will not be required for stone backfill material. Do not use sheepsfoot or grid-type rollers for compacting backfill within the reinforced backfill.

7.8.4 Achieve compaction within 3 feet of the back face of the wall; pipe encased pile, or pile, by at least 3 passes of a lightweight walk behind vibratory plate or roller. In order to determine the number of passes needed to compact the area within 3 feet of the back face of the wall, establish a test strip area 3 feet or farther from the back face of the wall, measuring a minimum of 3 feet by 5 feet within the reinforced backfill and compact it with a lightweight walk behind vibratory plate or roller. Ensure that the moisture content of the backfill material prior to and during compaction is uniformly distributed throughout each layer. Place stone backfill in 6 inch lifts within 3 feet of the back face of the wall and compact by at least 4 passes of a lightweight walk behind vibratory plate or roller.

7.8.5 Ensure that the granular backfill materials including screenings have a placement moisture content not more than the optimum moisture content. Remove and rework granular backfill material and/or screenings with placement moisture content in excess of the optimum moisture content until the moisture content is uniformly acceptable throughout the entire lift.

7.8.6 Use a maximum lift thickness (loose) of 8 inches for both granular and stone backfill. Within 3 feet of the face of the MSE wall, place a maximum lift thickness (loose) of 6 inches for both granular and stone backfill. Decrease these lift thicknesses if necessary to obtain the required density. Accomplish backfill compaction without disturbance or distortion of the reinforcement. Maintain a minimum of 6 inches of backfill material at all times between the compaction equipment and the soil reinforcement.

7.8.7 At the end of each day's operations, shape the last level of backfill to permit runoff of rainwater away from the wall face. In addition, do not allow surface runoff from adjacent areas to enter the wall reinforcement zone until this zone is protected from infiltration. Repair any damage or movement caused by erosion, sloughing, or saturation of the reinforced backfill or retained backfill at no expense to the Department.

7.9 **Soil Reinforcement Placement**

7.9.1 **General:** Install the soil reinforcement in accordance with the Wall Manufacturer's recommendations and these specifications. Place the soil reinforcement within the layers of the compacted backfill material at the locations shown in the Shop Plans. Only place that amount of soil reinforcement required for immediately pending work to prevent undue damage. Place soil reinforcement with the strongest direction of soil reinforcement perpendicular to the wall face, unless otherwise shown in the Shop Plans. Connect the soil reinforcement to the MSE wall facing in accordance with the Wall Manufacturer's recommendations. Next lay the soil reinforcement flat and uniformly tension it to remove any slack in the connection or soil reinforcement material. Once the reinforcement is connected to the panel, the amount of slack shall not exceed 1/8 inch between the connector and the reinforcement during field installation. Where wall geometry causes soil reinforcement to overlap, provide a minimum vertical separation of 3 inches between overlapping reinforcements.

7.9.2 **Construction Tolerances**

7.9.2.1 Erect walls with precast concrete panel facing units per the following requirements:

- Ensure vertical and horizontal alignment of the wall face does not vary by more than 3/4 inch when measured along a 10-foot straight edge, and along 3-foot straight edge for curved wall sections.
- The overall vertical plumbness tolerance (allowable variation from the offset batter shown on the Plans) from top to bottom of the wall is 1/2 inch per 10 feet of wall height. Ensure walls are constructed within tolerance. Wall acceptability related to plumbness will be determined after allowance is given for the offset batter of MSE wall facing. Negative batter is not acceptable.
- Make certain that the maximum allowable out of plane offset between panels at the joint does not exceed 3/8 inches. Ensure that the final horizontal and vertical joint opening is 3/4 ± 1/4 inch.

7.9.2.2 Erect walls with modular concrete block facing units per the following requirements:

- Ensure vertical and horizontal alignment of the wall face does not vary by more than 3/4 inch when measured along a 10-foot straight edge, and along 3-foot straight edge for curved wall sections.
- The overall vertical plumbness tolerance (allowable variation from the offset batter shown on the Plans) from top to bottom of the wall is 1-1/4 inch per 10 feet of wall height. Ensure walls are constructed within tolerance. Wall acceptability related to plumbness will be determined after allowance is given for the offset batter of MSE wall facing. Negative batter is not acceptable.
- Level the first row of units from unit-to-unit and from front-to-back. Use the tail of the units for alignment and measurement.
- Lay all units snug or to within 1/16 inch together and parallel to the straight or curved line of the wall face.
- Dry-stack all blocks and place each block evenly spanning the joint in the row below (running bond). Shim or grind to control the elevations of any two adjacent blocks to within 1/16 inch.
- Check the top of blocks with a minimum length of 3 feet long straight edge bubble level. Grind high points identified by the straight edge. Check block front to back tilting frequently, and correct by shimming no later than after 3 completed courses.

7.9.2.3 Ensure that temporary MSE wall facing used for 2-stage construction vertical and horizontal alignment construction tolerance does not exceed 2 inches when measured along a 10-foot straight edge. Negative batter is not acceptable.

7.9.3 **Surcharge:** Should the Plans indicate an earth surcharge to be placed over the reinforced zone, retain the surcharge using a temporary wall. The temporary wall may be built with a temporary MSE wall or other approved method. Place the face of the temporary surcharge wall approximately 1 foot from the permanent wall face. Ensure that the top surface of the surcharge allows the surface water to drain away from the wall. A geotextile separation fabric may be placed over the reinforced zone prior to placing the surcharge material.

7.9.4 **Abutment Piling:** If abutment piles are placed within the reinforced zone, case the piles through the reinforced backfill and adhere to the following requirements and sequence.

- Drive all piles within the reinforced zone prior to MSE wall construction.
- Encase each pile in a Smooth Wall or Corrugated Galvanized Steel (SWCGS) pipe of sufficient thickness to prevent buckling or distortion during placement and compaction of wall backfill. Include cost of encasement in the cost of the MSE wall.
- Externally stabilize the SWCGS pipe to prevent the pipe from coming in contact with the pile during backfilling of the wall.
- Extend the SWCGS pipe from the bottom of the backfill to 2 inches below the bottom of the bridge abutment cap.
- After positioning, seal the top of the SWCGS pipe to prevent debris accumulation during placement of wall backfill, and keep the pipe sealed until the pipe is filled with granular material.
- Unseal the pipe and fill the SWCGS pipe loosely with granular material after completion of wall construction to the satisfaction of the RCE unless otherwise noted on the plans.

8.0 MEASUREMENT

8.1 **MSE Retaining Wall:** The quantity for the pay item MSE Retaining Wall (of the type specified) is the area of the face of MSE wall constructed and is measured by the square foot (SF). The MSE Retaining Wall is measured vertically from the top of the leveling pad to the top of the wall as shown in the approved Shop Plans for the MSE wall profile, complete, and accepted. There will be no separate measurements for precast concrete panels, modular concrete blocks, temporary facing, galvanized steel reinforcing and tie strips or galvanized steel mesh and mesh connectors or geosynthetic reinforcement, geotextile for drainage filtration, reflective cracking geogrid, bearing pads, leveling pad, perforated pipe, drain pipe, SWCGS pipe, or other incidental items required for construction of the MSE wall. Field revisions made to the length and/or height of the MSE wall from the specified dimensions on the Shop Plans for the convenience of the contractor will not be included in the plan quantity.

8.2 **MSE Retaining Wall Backfill:** The quantity for the pay item MSE Retaining Wall Backfill (of the specified material) is the volume of the material specified for permanent MSE walls and is measured by the cubic yard (CY) in-place, complete, and accepted. The volume is measured as follows:

The depth is measured between the bottom elevation of the coping and the elevation of the top of the leveling pad. The width is measured between the

vertical planes located along the back of the MSE wall facing and 1 foot outside and parallel to the back end of the soil reinforcement at the leveling pad elevation as shown on the accepted Shop Plans. The length is measured from beginning to end of wall along the MSE wall stationing.

8.3 **Coping:** The quantity for the item Coping for MSE Retaining Wall (Roadway or Bridge) is the length of the cast-in-place or precast concrete coping and is measured by the linear foot (LF) along the length of the top of the wall in-place, complete, and accepted. There is no separate measurement for leveling concrete, dowels, grout, concrete, steel reinforcement, bearing pads, joint filler, or other incidental items required for construction of the coping. If no revisions are made to the length of the MSE wall from the specified dimensions on the Shop Plans, field measurement of the coping is not required and the quantity is the Shop Plan quantity.

8.4 **Structure Excavation:** When indicated in the plans for MSE walls, the quantity for the item Structure Excavation for Retaining Walls is the volume of material actually removed and is measured by the cubic yard (CY), complete, and accepted. The volume is measured as follows:

The depth is measured between the elevation of the original ground surface and the elevation of the top of the leveling pad. The width is measured between the vertical planes located 2 feet outside of and parallel to the front facing of the MSE wall located at the leveling pad and 3 feet outside and parallel to the back end of the soil reinforcement at the leveling pad elevation as shown on the accepted Shop Plans. The length is measured from beginning to end of wall along the MSE wall stationing. Material removed outside of this area is not included in the quantity, except where specifically authorized in writing by the RCE.

8.5 **Geomembrane:** When indicated in the plans for MSE walls, the quantity for the item Geomembrane will be computed based on the total area of geomembrane shown in the plans, exclusive of the wastage from gluing or welding all seams. Any wastage of the geomembrane from gluing or welding is considered incidental to construction.

9.0 PAYMENT

9.1 MSE Retaining Wall

9.1.1 Payment for the accepted quantity of MSE Retaining Wall (of the type specified), measured in accordance with Subsection 8.1 is determined using the contract unit bid price for the applicable pay item. Payment is full compensation for constructing MSE retaining walls as specified or directed and includes, but is not limited to, furnishing and installing precast concrete panels or modular concrete blocks, galvanized steel reinforcing and tie strips or galvanized steel mesh and mesh connectors or geosynthetic reinforcement, geotextile for drainage filtration, reflective cracking geogrid, bearing pads, leveling pad, temporary facing, SWCGS pipe, and drainage systems (even when not shown on the Plans); material testing; and all other materials, labor, equipment, tools, supplies, transportation, and incidentals necessary to fulfill the requirements of the pay item in accordance with the Plans, the Specifications, and other terms of the Contract. The MSE wall internal design is considered incidental to the construction of the MSE Wall. When changes in the work are ordered by the RCE in writing which vary the square foot of MSE retaining wall quantity shown in the Shop Plans, quantities will be adjusted to reflect the field changes.

9.1.2 Payment for MSE wall construction will not be made until the MSE wall material certifications and MSE wall reinforced backfill material tests have been reviewed and accepted by the Office of Materials and Research (OMR).

9.2 **MSE Retaining Wall Backfill Material:** Payment for the accepted quantity of MSE Retaining Wall Backfill (of the specified material), measured in accordance with Subsection 8.2, is determined using the contract unit bid price for the applicable pay item. Payment is full compensation for furnishing, placing, and compacting the specified backfill material as specified or directed and includes all other materials, labor, equipment, tools, supplies, transportation, and incidentals necessary to fulfill the requirements of the pay item in accordance with the Project Plans, the Specifications, and other terms of the Contract.

9.3 **Coping:** Payment for the accepted quantity of Coping for MSE Retaining Wall (Roadway or Bridge), measured in accordance with Subsection 8.3, is determined using the contract unit bid price for the applicable pay item. Payment is full compensation for constructing cast-in-place or precast concrete coping on top of the MSE retaining wall as specified or directed and includes furnishing and installing leveling concrete, dowels, grout, concrete, bearing pads, joint filler, steel reinforcement, all other materials, labor, equipment, tools, supplies, transportation, and incidentals necessary to fulfill the requirements of the pay item in accordance with the Project Plans, the Specifications, and other terms of the Contract.

9.4 **Structure Excavation:** Payment for the accepted quantity for Structure Excavation for Retaining Walls measured in accordance with Subsection 8.4, is full compensation for excavation of material necessary for the construction of retaining walls as specified or directed and includes removing and disposing of unsuitable material and backfilling with suitable material obtained from sources outside the limits of the roadway, and all other materials, labor, equipment, tools, supplies, transportation, and incidentals necessary to complete the work in accordance with the Project Plans, the Specifications, and other terms of the Contract.

9.5 **Geomembranes:** Payment for the accepted quantity of Geomembrane measured in accordance with Subsection 8.5 is full compensation for materials meeting the requirements of Subsection 5.8.3, installation and gluing of welding of geomembrane, labor, equipment, tools, supplies, transportation, and incidentals necessary to complete the work in accordance with the Project Plans, the Specifications, and other terms of the Contract.

9.6 **Pay Items**

9.6.1 Payment for each item includes all direct and indirect costs and expenses necessary to complete the work.

9.6.2 Pay items under this Section include the following:

Item No.	**Pay Item**	**Pay Unit**
2041005	STRUCTURE EXCAVATION FOR RETAINING WALL	CY
7137006	MSE RETAINING WALL BACKFILL (GRANULAR)	CY
7137007	MSE RETAINING WALL BACKFILL (STONE)	CY
7137120	MSE RET. WALL (BLOCK FACING) ROADWAY	SF
7137130	MSE RET. WALL (PANEL FACING) ROADWAY	SF
7137190	COPING FOR MSE RET. WALL (ROADWAY)	LF
7137230	MSE RET. WALL (PANEL FACING) BRIDGE	SF
7137290	COPING FOR MSE RET. WALL (BRIDGE)	LF
7137901	GEOMEMBRANE	SY