

SPECIAL PROVISION

SPECIFICATION 990 - MECHANICALLY STABILIZED EARTH (MSE) RETAINING WALL SYSTEM

990-1 DESCRIPTION

990-1.01 Scope

a. This work shall consist of furnishing all materials and installation of Mechanically Stabilized Earth (MSE) Retaining Wall System including facing elements, soil reinforcement, connecting devices, joint filler, bearing pads, geotextile filter, reinforced granular backfill material, subsurface drainage, modifications for obstructions, reinforced concrete cap, shop drawings, submittals and any other incidentals required by the Manufacturer/Supplier of the MSE Retaining Wall System in accordance with these specifications and in compliance with the lines and grades, dimensions and details shown on the project plans, contract documents and as directed by the Engineer.

b. Works shall also include the excavation required for the construction of the MSE Retaining Wall System conforming to the requirements of Specification 206 - Excavation for Structures.

c. The Authority is not responsible for errors or omissions in the design calculations and shop drawings submitted by the Contractor. Acceptance by the Authority of the final working drawings submitted by the contractor shall not relieve the Contractor of any responsibility under the contract for the successful completion of the work.

d. Each word, sentence, section or article of this document is independent. Not applying parts of it does not imply that it cannot be enforced afterwards nor invalidates the remaining provisions.

990-2 MATERIALS

990-2.01 Materials shall conform to the applicable specifications of the Standard Specifications for Road and Bridge Construction and as required on the details and notes in plans. The following materials shall meet the applicable specified requirements:

990-2.02 Facing Elements – The facing elements for the MSE Retaining Wall System shall be designed to resist the horizontal force in the soil reinforcements at the reinforcement to facing connection, potential stresses from the compaction process during the erection of the retaining wall and shall control the aesthetics of the entire system. The facing elements shall be among the following types:

a. Precast Reinforced Concrete Facing (PRCF) Units – The PRCF Units shall conform with the following requirements:

1. Concrete for PRCF Units shall be Class IV (General Use) Concrete with

SPECIAL PROVISION

SPECIFICATION 990 - MECHANICALLY STABILIZED EARTH (MSE) RETAINING WALL SYSTEM

Permeability Level as indicated in the plans and conforming to the requirements of Specification 934 – Structural Concrete. The units shall be fully supported until the concrete reaches a minimum compressive strength of 1,000 psi (6.9 MPa). The units may be shipped after reaching a minimum compressive strength of 3,400 psi (23.4 MPa). The units may be installed after the concrete reaches a minimum compressive strength of 3,400 psi (23.4 MPa) with the evaluation and approval of the Engineer.

2. *Identification and Markings* - The date of manufacture, production lot number, and any other identification mark shall be clearly scribed on an unexposed face of each panel.
3. *Handling, Storage and Shipping* - All units shall be handled, store, and shipped in such a manner as to eliminate the risk of damages such as discoloration, cracking, fractures, and excessive bending. Panels in storage shall be supported in firm blocking to protect the panel connection devices and the exposed exterior finish.
4. The PRCF Units shall be cast on a horizontal surface with the front face of the panel at the bottom of the form. Connection hardware shall be set in the rear face. The concrete in each PRCF Units panel shall be placed without interruption and shall be consolidated by deploying an approved vibrator, supplemented by such hand tamping as may be necessary to force the concrete into the corner of the forms, and to eliminate the formation of stone pockets or cleavage planes.
5. *Tolerances* - All PRCF Units shall be manufactured within the following dimension tolerances:
 - i. Panel Dimensions - Position of panel connection devices within 1 inch (25 mm), except for coil and loop imbeds which shall be 3/16 inch (5 mm). All other dimensions within 3/16 inch (5 mm).
 - ii. Panel Squareness as determined by the difference between the two diagonals shall not exceed 1/2 inch (13 mm).
 - iii. Panel Exposed Surface Finish - Surface defects on smooth formed surfaces measured over the smaller surface dimension of the panel shall not exceed 1/8 inch (3 mm). Surface defects on the textured-finish surfaces measured over the smaller surface dimension of the panel shall not exceed inch 5/16 inch (8 mm).

SPECIAL PROVISION

SPECIFICATION 990 - MECHANICALLY STABILIZED EARTH (MSE) RETAINING WALL SYSTEM

- iv. Panel Rear (Non-Exposed) Surface Finish - Rear faces of PRCF Units shall receive a Class I finish in accordance with Specification 934 – Structural Concrete.
 - v. Connection hardware shall be cast in the PRCF Units such that all connectors are in alignment and able to transfer full and even load to the soil reinforcement.
6. *Reinforcing Steel* - Reinforcing steel bars for panels shall meet requirements of Specification 602 – Reinforcing Steel. Equivalent deformed welded wire mesh, Grade 70 complying with ASTM A1064 or ASTM A184 may be used.
7. *Sampling and Testing of Concrete for PRCF Units* – Sampling frequency for compressive strength and permeability tests of concrete as required in plans shall follow the provisions and requirements of Specification 934 – Structural Concrete, Article 934-2.09 - Sampling and Testing. Additional sets of specimens will be tested as needed to determine the 1,000 psi (6.9 MPa) of compressive strength threshold for a fully supported PRCF Unit, and the 3,400 psi (23.4 MPa) threshold for shipping the PRCF Unit to the job site. The Manufacturer/Supplier's quality control for sampling and testing shall be conducted at an ASTM and AASHTO accredited laboratory. The Contractor shall submit a detailed report documenting the testing results. The Authority reserves the right to perform random sampling and testing in accordance with this specification to verify compliance. The Authority may reject the PRCF Units based on the results obtained.
8. *PRCF Units Joint Material* - Where the wall wraps around an inside corner, a corner block panel shall be provided with flange extensions that will allow for differential movement without exposing the panel joints. The back face of vertical and horizontal joints shall be covered with geotextile filter. Joint filler, bearing pads, and geotextile filter shall be as recommended by the MSE Retaining Wall Manufacturer/Supplier and shall meet the requirements shown on the approved shop drawings. If required, as indicated on the plans, flexible open-cell polyurethane foam strips shall be used for filler for vertical joints between panels, and in horizontal joints where pads are used. All joints between panels on the back side of the wall shall be covered with a Class 2 non-woven geotextile meeting the requirements for filtration applications as specified by AASHTO M 288. The minimum width shall be one foot.

All horizontal and diagonal joints between panels shall include bearing pads. Bearing pads shall meet or exceed the following material requirements:

SPECIAL PROVISION

SPECIFICATION 990 - MECHANICALLY STABILIZED EARTH (MSE) RETAINING WALL SYSTEM

- i. Preformed Ethylene Propylene Diene Monomer (EPDM) rubber pads conforming to ASTM D2000, Grade 2, Type A, Class A with a Durometer Hardness of 70.
- ii. Preformed High Density Polyethylene (HDPE) pads with a minimum density of 56.06 lb/ft³ (0.946 g/cm³) conforming to ASTM D1505.

The stiffness (axial and lateral), size, and number of bearing pads shall be determined such that the final joint opening shall be $3/4 \pm 1/8$ inches (19 ± 3 mm) unless otherwise shown on the plans.

b. Modular Concrete Masonry Block Wall (MBW) Units – The MBW Units shall conform with the following requirements:

1. Cementitious material for MBW Units shall be Portland Cement conforming to the requirements of AASHTO M 85 (ASTM C 150), or modified as follows:
 - i. Limestone-calcium carbonate, with a minimum 85% content, may be added to the cement, provided these requirements of C 150 as modified are met; (1) limitation on insoluble residue 1.5%; (2) limitation on air content to mortar–volume percent, 22% maximum; and (3) limitations of loss of ignition – 7%.

Blended Cements and Pozzolan conforming to the requirements of AASHTO M 295 (ASTM C 618) and Blast Furnace Slag Cement conforming to the requirements of AASHTO M 302 (ASTM C 989).

2. Aggregates shall conform to the following specifications:
 - i. Normal Weight Aggregates – ASTM C 33
 - ii. Lightweight Aggregates – ASTM C 331
3. The MBW Units shall conform to the following mechanical and physical requirements measured in accordance with appropriate references:
 - i. Minimum compressive strength of 3,000 psi (21.0 MPa) in accordance with ASTM C 140.
 - ii. Maximum water absorption of 5% after 24 hours.

SPECIAL PROVISION

SPECIFICATION 990 - MECHANICALLY STABILIZED EARTH (MSE) RETAINING WALL SYSTEM

- iii. Height of each unit between 4 inches to 12 inches (100 mm to 300 mm)
 - iv. Exposed face length between 8 inches to 18 inches (200 mm to 450 mm)
 - v. Nominal front to back width ratio of 1.5 perpendicular to wall face.
4. Cap Units shall be cast to or attached to the top of modular block facing units in strict accordance with the requirements of the manufacturer of the blocks and the adhesive. The surface of the block units under the cap units shall be clear of all debris and standing water before the approved adhesive is placed. Cap units shall conform to the same mechanical and material requirements of the MBW Units
5. *Handling, Storage and Shipping* - All units shall be handled, store, and shipped in such a manner as to eliminate the risk of damages such as discoloration, cracking, fractures, and any other defect that would interfere with the proper placing of the unit or significantly impair the performance of the MSE Retaining Wall System. Units shall be visually efflorescence free.
6. *Tolerances* - All units shall be manufactured within the following dimension tolerances:
- i. The length and width of each MBW Unit shall be within $\pm 1/8$ inch (3 mm) of the specified dimension. Hollow units shall have a minimum wall thickness of 1.25 inches (32 mm).
 - ii. The height of each individual block shall be within $\pm 1/16$ inch (1.5 mm) of the specified dimension.
 - iii. When a broken (split) face finish is required, the dimension of the front face shall be within ± 1.0 inch (25 mm) of the theoretical dimension of the unit.
7. *Sampling and Testing of the MBW Units* – Sampling and testing for compressive strength, water absorption and unit weight shall be on a 1,000 units per lot basis, submitted at the frequency of one set per lot. The Manufacturer/Supplier's quality control for sampling and testing shall be conducted at a qualified laboratory. The Contractor shall submit a detailed report documenting the testing results. The Authority reserves the right to perform random sampling and testing in accordance with this specification to

SPECIAL PROVISION

SPECIFICATION 990 - MECHANICALLY STABILIZED EARTH (MSE) RETAINING WALL SYSTEM

verify compliance. The Authority may reject the MBW Units based on the results obtained.

c. Welded Wire Mesh (WWM) Units – The WWM Units shall conform with the following requirements:

1. WWM fabric for facing shall be shop fabricated of cold drawn steel wire and shall be welded into the finish mesh fabric conforming to the requirements of ASTM A 1064 with a minimum yield strength of 65 ksi (450 MPa). It shall be hot dipped galvanized with a minimum galvanization coating of 2.0 oz/ft² (605 g/m²) or 3.4 mils (85 µm) thickness is conforming to the requirements of AASHTO M 111 (ASTM A123)

d. Polyethylene Textured Strip Cell (PTSC) Units – The PTSC facing units shall conform with the following requirements:

1. The PTSC facing shall consist of a polyethylene strip with a density between 58.4 – 60.2 lb/ft³ (0.935 – 0.965 g/cm³) conforming to the requirements of ASTM D 1505. The polyethylene shall have stabilization for ultra-violet light by means of carbon black or hindered amine stabilizers (HALS).
2. *Identification and Markings* – The PTSC facing units shall identify by a base resin lot number and production lot number.
3. *Handling, Storage and Shipping* - PTSC facing units shall be shipped in the Manufacturer's original and unopened containers, with all labels clearly identifying product name and Manufacturer/Supplier. The material shall be stored conforming to the Manufacturer/Supplier instructions and out of direct sun light. The PTSC facing units shall be delivered, unloaded and installed in a manner to prevent damage that could significantly impair the performance of the MSE Retaining Wall System.
4. *Tolerances* - All units shall be manufactured within the following dimension tolerances:
 - i. Strips shall have a thickness of 50 mils (1.27 mm) minus 5 percent, plus 10 percent conforming to the requirements of ASTM D5199.
 - ii. Textured strips shall have a thickness of 60 mils ± 6 mils (1.52 mm ± 0.15 mm) conforming to the requirements of ASTM D5199.
 - iii. The nominal dimensions for the individual cells shall be ± 10 percent as follows:

SPECIAL PROVISION

SPECIFICATION 990 - MECHANICALLY STABILIZED EARTH (MSE) RETAINING WALL SYSTEM

1. Length = 10.5 inches (267 mm)
2. Width = 13.0 inches (330 mm)
3. Nominal Depth = 6 inches (150 mm)
4. Nominal Area = 68.3 in² (440 cm²) ± 1 percent

990-2.03 Soil Reinforcement – The soil reinforcement shall be suitable for the MSE Retaining Wall System shown on plans and according to Manufacturers/Supplier recommendations in the approved shop drawings. It shall be designed to resist the horizontal forces in the soil mass and potential stresses from the compaction process during the erection of the retaining wall. The soil reinforcement shall be among the following types:

a. Metallic Reinforcing Strips and Tie Strips – The metallic reinforcing strips and tie strips shall conform with the following requirements:

1. Reinforcing strips shall be hot rolled from bars to the required shape and dimensions conforming to the requirements of ASTM A572, Grade 65.
2. Tie strips shall be shop fabricated of hot rolled steel conforming to the requirements of ASTM A1011, Grade 50. The minimum bending radius of the tie strips shall be $\frac{3}{8}$ of an inch.
3. Metallic reinforcing strips and tie strips shall be hot dipped galvanized with a minimum galvanization coating of 2.0 oz/ft² (605 g/m²) or 3.4 mils (85 µm) thickness conforming to the requirements of AASHTO M 111 (ASTM A 123).

b. Metallic Reinforcing Mesh – The metallic reinforcing mesh shall comply with the following requirements:

1. Metallic Reinforced Mesh shall be shop fabricated of cold drawn steel wire and shall be welded into the finish mesh fabric conforming to the requirements of ASTM A 1064 with a minimum yield strength of 65 ksi (450 MPa). It shall be hot dipped galvanized with a minimum galvanization coating of 2.0 oz/ft² (605 g/m²) or 3.4 mils (85 µm) thickness conforming to the requirements of AASHTO M 111 (ASTM A 123).

c. Geosynthetic Reinforcement – The Manufacturer/Supplier of the MSE Retaining Wall System shall recommend geosynthetic reinforcements that have been evaluated through the *National Transportation Product Evaluation Program (NTPEP)* for the ultimate strength of the reinforcement, durability, installation damage reduction factor RF_{ID} and creep reduction factor RF_{CR}. The wall Manufacturer/Supplier may not select

SPECIAL PROVISION**SPECIFICATION 990 -
MECHANICALLY STABILIZED EARTH (MSE) RETAINING WALL SYSTEM**

installation damage reduction factor RF_{ID} and creep reduction factor RF_{CR} less than the results obtained through the NTPEP program. The nominal long-term tensile design strength (T_{all}) of specific geosynthetic material shall meet or exceed the creep and durability reduction factors required by the wall Manufacturer/Supplier, as well as those required by the latest *AASHTO LRFD Bridge Design Specifications*. If the Manufacturer/Supplier internal stability design calls for a geosynthetic that has not been evaluated by the NTPEP, the Manufacturer/Supplier shall justify it in the design calculations. In this case, the most restrictive reduction factors between those required by the Manufacturer/Supplier and the *AASHTO LRFD Bridge Design Specifications* shall prevail. The geosynthetic reinforcement shall comply with the following requirements:

1. *Geogrids* – Uniaxial or biaxial woven yarns composed either of polyethylene, polyester resin or polypropylene. The minimum ultimate tensile strength and minimum tensile strength at 2% of strain shall conform to the requirements of ASTM D 6637.
2. *Geotextiles* – Uniaxial or biaxial regular closed network pattern of connected geotextiles composed of polyester resin or polypropylene yarns. The minimum ultimate tensile strength and minimum tensile strength at 2% of strain shall conform to the requirements of ASTM D 4595.

990-2.04 Connecting Devices – The connecting devices shall include connector pins, fasteners, and shear pins suitable for the facing element of the MSE Retaining Wall System shown on plans. These devices shall be among the following types as indicated by the Manufacturer/Supplier of the system in the approved shop drawings:

a. Connector Pins and Mat Bars: Connector pins and mat bars shall be fabricated and connected to the soil reinforcement mats as required by the Manufacturer/Supplier and shown in the approved shop drawings. They shall be hot dipped galvanized with a minimum galvanization coating of 2.0 oz/ft² (605 g/m²) or 3.4 mils (85 μ m) thickness conforming to the requirements of AASHTO M 111 (ASTM A 123).

b. Connector pins and mat bars shall be fabricated of cold drawn steel wire conforming to the requirements of ASTM A1064.

c. Fasteners: Fasteners shall conform to ASTM F3125, Grade A325, and hot-dipped galvanized conforming to the requirements of ASTM F2329.

d. Shear Pins: Shear pins shall consist of a non-degrading polymer or hot-dipped galvanized steel fabricated and connected to the soil reinforcement mats or to provide alignment and interlocking between the facing units. Shear pins shall be capable of holding the geosynthetic reinforcement in the proper position during backfilling operations. Steel shear pins shall be galvanized in accordance with AASHTO M-111 (ASTM A123).

SPECIAL PROVISION**SPECIFICATION 990 -
MECHANICALLY STABILIZED EARTH (MSE) RETAINING WALL SYSTEM**

990-2.05 Concrete Leveling Pad – The leveling pad shall be constructed of unreinforced Concrete Class A or as indicated in the plans and conforming to the requirements of Specification 601 – Structural Concrete. The minimum width of the leveling pad shall be the width of the facing unit plus 8 in (200 mm), centerline of the leveling pad shall be within ½ of an inch (13 mm) from design location. When the facing units are centered on the leveling pad, the leveling pad shall extend approximately 4 in (100mm) beyond the limits of the facing unit as measured in the direction perpendicular to the face of the wall.

990-2.06 Reinforced Concrete Cap - The reinforced concrete cap shall be Class A or as indicated in the plans and approved shop drawings and conforming to the requirements of Specification 601 – Structural Concrete. Reinforcing steel bars for the concrete cap shall meet requirements of Specification 602 – Reinforcing Steel.

990-2.07 Reinforced Granular Backfill Material - The granular material used in the reinforced volume shall be free from shale, organic matter, mica, gypsum, smectite, montmorillonite, soft poor durability particles or otherwise deleterious materials and shall conform to the gradation limits in Table 990-1. The minimum backfill angle of internal friction shall be of 34 degrees, and it shall be determined by a Direct Shear Test as per AASHTO T 236 (ASTM D3080). If a minimum friction angle of 38 degrees is not obtained by using the standard direct shear box, a new direct shear box shall be used with a size of 10 times the maximum particle size being tested, using the full gradation of the material.

Table 990-1: Reinforced Granular Backfill Material Requirements

Gradation	
<u>Sieve Size</u>	<u>Percent Passing</u>
1 inch	100
½ inch	0-50
No. 4	0-10
No. 50	0-5
<i>Plasticity Index (AASHTO T-90): PI ≤ 6</i>	
<i>Soundness (AASHTO T-104):</i> The backfill shall be substantially free of shale or other poor durability particles. It shall have a magnesium sulfate loss of less than 30 percent after four cycles (or a sodium value less than 15 percent after 5 cycles). <u><i>Aggregate sources with recent testing data within the past year may submit previous testing results for soundness determination.</i></u>	

990-2.08 Retained Backfill Material – Retained backfill material shall be Borrow Class B conforming to the requirements of Specification 203 – Excavation and

SPECIAL PROVISION

SPECIFICATION 990 - MECHANICALLY STABILIZED EARTH (MSE) RETAINING WALL SYSTEM

Embankment. In case that the backfill shall be below ground water elevation, the fraction of the material passing the No. 200 sieve shall not exceed 15 percent.

990-2.09 Basis of Acceptance - The Contractor shall submit to the Engineer a Certificate of Compliance, according to article 106.06 of the General Provisions, certifying the above materials comply with the applicable contract specification and this document, including a copy of all test results performed by the Contractor necessary to assure compliance prior to beginning of works.

990-3 CONSTRUCTION REQUIREMENTS

990-3.01 General - The works for the MSE Retaining Wall System shall be accomplished as required in the contract documents and in coordination with other operations in progress within project area.

990-3.02 MSE Retaining Wall System Submittals - The submittals required shall include shop drawings, supporting design calculations, verification of experience from the Manufacturer/Supplier and a transmittal letter. The transmittal letter shall only list the documents included in the submittal. No technical information shall be included in the transmittal letter.

The Contractor shall submit shop drawings, a complete set of installation and construction procedures, supporting design calculations, and verification of experience duly signed and sealed by a Licensed Engineer in Puerto Rico for evaluation and approval by the Engineer prior to the beginning of works. The calculations and shop drawings shall comply with the AASHTO LRFD Bridge Design Specifications, 9th Edition and interims or latest edition for internal and external stability at the Strength, Service and Extreme Limit States.

The Authority assumes no responsibility for errors or omissions in the submittals. Acceptance of the final shop drawings, supporting design calculations and any other documents related to the design and construction of the **MSE Retaining Wall System** submitted by the Contractor shall not relieve it of any responsibility under the contract for the successful completion of the work.

Submittals shall include at least the following:

a. Shop drawings, design calculations, design parameters including design life duly signed and sealed by a Professional Engineer licensed and registered under the requirements of law of the Commonwealth of Puerto Rico. The calculations and shop drawings shall comply with the AASHTO LRFD Bridge Design Specifications, 9th Edition and interims or latest edition for internal and external stability at the Strength, Service and Extreme Limit States. The shop drawings shall be submitted to the Engineer for review and approval not later than forty-five (45) calendar days after the issuance of the Notice to

SPECIAL PROVISION

SPECIFICATION 990 - MECHANICALLY STABILIZED EARTH (MSE) RETAINING WALL SYSTEM

Proceed. The Engineer will have a period of twenty-one (21) calendar days after receiving the submittals to review them. If additional time is required by PRHTA to complete the revisions, a time extension may be granted to the Contractor. The Contractor shall have a maximum of fifteen (15) calendar days to perform revisions on previously submitted revised submittals. No time extension will be granted to the Contractor for additional time required by the Authority to approve a previously submitted revised submittal.

- b. Layout of the wall including plan and elevation views.
- c. Existing ground elevations and utilities impacted by the wall and field data verified by the Contractor for each location.
- d. Complete details of all elements and component parts required for the proper construction of the system at each location and any required accommodations for drainage systems, foundation subgrades or other facilities shown on the contract documents.
- e. The submittals shall include details of any special design requirements. These special design requirements may include, but are not limited to; structural frames to place reinforcements around obstructions such as deep foundations and storm drain crossings, drainage systems, placement sequence of drainage and unit core fill with respect to reinforced (structure) fill behind a wall facing, guardrail post installation, scour protection, foundation subgrade modification, all corner details (acute, obtuse and 90 degrees), slip joints, connection details of MSE Retaining Wall with other cast-in-place structures, wedges, shims and other devices such as clamps and bracing to establish and maintain vertical and horizontal wall facing alignments.
- f. A complete listing of components and materials specifications.
- g. Accurate description of all equipment to be used during the procedures, including contingency equipment.
- h. Quality control procedures as well as the contract quality assurance and acceptance requirements.
- i. Location of stockpiles, storage, and handling of the different components for the MSE Retaining Wall System within the project site.
- j. Equipment movement and traffic maintenance within the project site during all construction activities related to MSE Retaining Wall System starting with the excavation. Where shoring is required, the Contractor shall submit to the Engineer the shoring design, outlining construction and removal procedures.
- k. Safety and security provisions.

SPECIAL PROVISION

SPECIFICATION 990 - MECHANICALLY STABILIZED EARTH (MSE) RETAINING WALL SYSTEM

l. The location of stockpiles, equipment movement and traffic maintenance, location of equipment during MSE Retaining Wall System erection and its general construction procedures shall be complemented with schematic drawings.

m. Other site-specific or project specific information required by the contract.

990-3.03 Reference Documents to be used for the Design and Construction of this item.

a. *AASHTO LRFD Bridge Design Specifications, 9th Edition and Interims or Latest Edition.*

b. *AASHTO Load and Resistance Factor Design (LRFD) Bridge Construction Specifications, 4th Edition and Interims or Latest Edition.*

c. *Design and Construction of Mechanically Stabilized Earth Walls and Reinforced Soil Slopes – Volume I & Volume II, Publications No. FHWA-NHI-10-024 & FHWA-NHI-10-025, November 2009.*

d. *PRHTA Design Directive 311 – “Muros con Suelos Mecánicamente Estabilizados”.*

990-3.04 MSE Retaining Wall System Pre-Installation Meeting – The Contractor and the Engineer shall coordinate and schedule a pre-construction meeting with at least 15 working days before beginning with the construction activities. The meeting attendance is compulsory for all representatives of the Contractor, Subcontractors, Manufacturer/Supplier and labor personnel involved in the MSE Retaining Wall System construction process. The Engineer may require at his discretion the presence of any additional personnel.

The presence of the Contractor, Subcontractors, MSE Retaining Wall System's Manufacturer/Supplier and MSE Retaining Wall System designer's representatives shall be mandatory. Construction of the MSE Retaining Wall System shall not start until the Contractor receives a written notification from the Engineer. The written notification will be issued once the complete wall package (shop drawings, calculations, and construction procedures) is approved. Fabrication of any of the wall components before the written notification shall be at the sole risk of the contractor.

990-3.05 Excavation - Excavation for the construction of mechanically stabilized walls shall be performed in accordance with the requirements of Specification 206 – Excavation for Structures. The Contractor shall excavate to the lines and grades shown on plans, shop drawings and any other instruction or document previously discussed at the

SPECIAL PROVISION

SPECIFICATION 990 - MECHANICALLY STABILIZED EARTH (MSE) RETAINING WALL SYSTEM

pre-construction meeting, or as directed by the Engineer. The Engineer with PRHTA Soil Engineering Office personnel will inspect and approve the excavation prior to the construction of the Concrete Leveling Pad.

The Contractor shall ensure that temporary slopes are safe during the period of MSE Retaining Wall System construction, and shall adhere to all applicable local, state, federal regulations, and the recommendations of the PRHTA Soil Engineering Office personnel assigned. During construction of the MSE Retaining Wall System, the Contractor shall design, construct, maintain, and when called for, remove temporary excavation support systems (shoring). Temporary excavation support systems may be left in place as long as they do not interfere with other construction procedures, and with the approval of the Engineer. The back slope of the excavation shall be benched.

990-3.06 Foundation Works - The foundation for the concrete leveling pad and the reinforced soil mass shall be graded level for a width equal to the length of reinforcement elements plus 1 foot (305 mm) on all sides according to the lines and grades shown on the plans, approved shop drawings or as directed by the Engineer. Prior to wall construction, except for construction on rock, the foundation shall be compacted with a smooth wheel vibratory roller. Any foundation soils found to be unsuitable shall be removed and replaced with foundation fill conforming to the requirements of Specification 207 - Foundation Fill

990-3.07 Concrete Leveling Pad - Cast-in-place leveling pads shall be cured for a minimum of 24 hours before placement of wall facing units. A geotextile shall be placed over the back of the area of any openings between the facing units and leveling pad steps. The geotextile shall extend a minimum of six inches beyond the edges of the opening. The opening shall be filled with concrete. The Concrete Leveling Pad shall be prepared to ensure full contact to the base surface of facing units.

990-3.08 Subsurface Drainage – Prior to wall erection, the Contractor shall install a subsurface drainage system as shown on plans, approved shop drawings or as instructed by the Engineer conforming to the requirements of Specification 605 – Underdrains.

990-3.09 Obstructions - Where obstructions, such as deep foundations or storm drains crossings are located in the reinforced backfill zone, unconnected or arbitrary cutting of reinforcements to avoid obstructions shall not be permitted. If the reinforcement layers must be partially or fully severed in the location of the obstruction, the surrounding reinforcement layers shall carry the additional load which would have been carried by the severed reinforcements. The additional capacity required by the surrounding reinforcement layers shall be analyzed by the Manufacturer/Supplier of the MSE Retaining Wall System. To consider internal vertical or horizontal obstructions refer to the *Design and Construction of Mechanically Stabilized Earth Walls and Reinforced Soil Slopes – Volume I & Volume II, Publications No. FHWA-NHI-10-024 & FHWA-NHI-10-025, November*

SPECIAL PROVISION

SPECIFICATION 990 - MECHANICALLY STABILIZED EARTH (MSE) RETAINING WALL SYSTEM

2009. A minimum offset of one diameter but not less than 3 feet (0.91 m) shall be maintained between the face of any vertical or horizontal obstruction crossing and the back face of the facing units.

990-3.10 MSE Retaining Wall Erection – Facing units, soil reinforcement, reinforced granular backfill material, retained backfill material, reinforced concrete cap, and incidentals shall be erected in accordance with the MSE Retaining Wall System Manufacturer/Supplier approved shop drawings, submittals and construction procedures. The Contractor shall be responsible for ensuring that a field representative from the wall Manufacturer/Supplier is available at the site during construction of the initial 10-foot height of the full length of wall, and as called upon thereafter by the Engineer, to assist the Contractor and/or Subcontractor. No deviation angle shall be permitted in the horizontal plane at any reinforcing level. Vertical deviation of the reinforcement shall be limited to a maximum of 15 degrees from normal to the face. All temporary construction aids (e.g., wedges, clamps, etc.) shall be in accordance with the MSE Retaining Wall Manufacturer's recommendations.

a. Placement Tolerances for MSE Retaining Walls with Precast Reinforced Concrete Facing (PRCF) Units:

1. The PRCF Units shall be placed such that their final position is as shown on the plans and approved shop drawings. As wall fill material is placed, the panels shall be maintained in the correct vertical alignment by means of temporary wedges, clamps, or bracing as recommended by the manufacturer. The Contractor shall install the joint filler, bearing pads, and geotextile filter as shown on the approved shop drawings. A minimum of two, but not more than three rows of unit wedges shall remain in place at all times during wall erection. Wedges shall be removed from lower rows as panel erection progresses as to prevent chipping or cracking of PRCF Units. The Contractor shall repair any damage to the erected the PRCF Units as directed by the Engineer and to the Engineer's satisfaction. No external wedges in front of the wall shall remain in place when the wall is complete.

Erection of walls with rigid facing shall be with the following tolerances:

- i. The overall vertical tolerance (plumbness) of the finished wall shall not exceed $\frac{1}{2}$ of an inch per 10 feet of wall height. Negative (outward leaning) batter is not acceptable.
- ii. The maximum permissible out-of-plane offset at any panel joint shall not exceed $\frac{3}{8}$ of an inch.

SPECIAL PROVISION

**SPECIFICATION 990 -
MECHANICALLY STABILIZED EARTH (MSE) RETAINING WALL SYSTEM**

- iii. The final horizontal and vertical joint gaps between adjacent facing panel units shall be within $\frac{1}{8}$ of an inch and $\frac{1}{4}$ of an inch, respectively, of the design final joint opening per the approved calculations.
- iv. Wall sections not conforming to these tolerances shall be removed and reinstalled at no additional cost to the Authority.

b. Placement Tolerances for MSE Retaining Walls with Modular Concrete Masonry Block Wall (MBW) Units:

- 1. Erection of walls with Modular Concrete Masonry Block Wall (MBW) Units shall be in accordance with the following tolerances:
 - i. Vertical and horizontal alignment of the wall face shall not vary by more than $\frac{3}{4}$ of an inch when measured along a 10-foot straightedge.
 - ii. Overall vertical tolerance (plumbness) of the wall shall not exceed $1\frac{1}{4}$ inches per 10 foot of wall height from the final wall batter. Negative (outward leaning) batter is not acceptable.
 - iii. Unless otherwise noted, all blocks shall be dry-stacked and placed with each block evenly spanning the joint in the row below (running bond). Shimming or grinding may be used to address elevations of any two adjacent blocks within $\frac{1}{16}$ of an inch.
 - iv. Maximum stacked vertical height of wall units, prior to wall fill and backfill placement and compaction, shall not exceed two (2) courses.
 - v. Cap units shall be glued to underlaying units with an adhesive recommended by the Manufacturer/Supplier and approved by the Engineer.
 - vi. Wall sections not conforming to these tolerances shall be removed and reinstalled at no additional cost to the Authority.

c. Placement Tolerances for MSE Retaining Walls with Welded Wire Mesh (WWM) or Polyethylene Textured Strip Cell facing:

SPECIAL PROVISION

**SPECIFICATION 990 -
MECHANICALLY STABILIZED EARTH (MSE) RETAINING WALL SYSTEM**

1. Erection of walls with Welded Wire Mesh (WWM) or Polyethylene Textured Strip Cell facing shall be in accordance with the following tolerances:
 - i. Vertical and horizontal alignment of the wall face shall not vary by more than two inches when measured along a 10-foot straightedge, or as shown in the plans and specifications.
 - ii. The overall vertical tolerance (plumbness) of the wall shall not exceed one inch per 10 feet of wall height. Negative (outward leaning) batter is not acceptable.
 - iii. The offset limit between consecutive rows of facing shall not exceed one inch from planned offset.
 - iv. Wall sections not conforming to these tolerances shall be removed and reinstalled at no additional cost to the Authority.

d. Mesh: Placement of Metallic Reinforcement: Strips and Tie Strips/Welded Wire

1. Metallic reinforcement elements shall be placed normal (perpendicular) to the face of the wall, unless otherwise shown on plans and shop drawings. All reinforcement shall be structurally connected to the wall face.
2. At each level of the soil reinforcement, the reinforced wall fill material shall be roughly leveled and compacted before placing the next layer of reinforcement. The reinforcement shall bear uniformly on the compacted reinforced soil from the connection to the wall to the free end of the reinforcing elements. The reinforcement placement elevation shall be at the connection elevation to within two inches higher than the connection elevation.
3. Bends in metallic reinforcement shall be smooth and with a gradual transition to ensure that galvanization remains intact.
4. The amount of slack shall not exceed 1/8 inch (3 mm) between the connector and the reinforcement during field installation.
5. Vertical and horizontal spacing of metallic reinforcements for flexible face (Welded Wire Mesh or similar) wall systems shall not exceed 18 inches (450 mm). The stiffness of the facing and spacing of reinforcements shall be such that the maximum local deformation between soil reinforcement layers shall

SPECIAL PROVISION

**SPECIFICATION 990 -
MECHANICALLY STABILIZED EARTH (MSE) RETAINING WALL SYSTEM**

be limited to less than 1½ inches (38 mm). Facing elements shall not yield in bending and tension.

e. Placement of Geosynthetic Reinforcement: Geogrids and Geotextiles:

1. Geosynthetic reinforcement shall be installed in accordance with the Manufacturer/Supplier's site-specific wall erection instructions, plans and shop drawings.
2. Geosynthetic reinforcement shall be placed in continuous longitudinal rolls in the direction of the main reinforcement. Joints parallel to the wall shall not be permitted, except as shown on the approved shop drawings.
3. Reinforcement coverage shall be 100 percent of embedment area unless otherwise shown in plans and shop drawings. Adjacent sections of geosynthetic reinforcement need not be overlapped except when exposed in a wrap-around face system, at which time the reinforcement rolls shall be overlapped or mechanically connected per the Manufacturer/Supplier's requirement.
4. During construction, the surface of the fill shall be kept approximately horizontal. Geosynthetic reinforcement shall be placed directly on the compacted horizontal fill surface. The reinforcement shall bear uniformly on the compacted reinforced soil from the connection to the wall to the free end of the reinforcing elements. The reinforcement placement elevation shall be at the connection elevation to within two inches higher than the connection elevation. Displacement of the geosynthetic reinforcement caused by wind or construction activities shall be avoided.
5. The maximum vertical spacing between layers of adjacent geosynthetic reinforcement shall not exceed 24 inches (0.60 m). For walls deriving any part of their connection capacity by friction the maximum vertical spacing of the reinforcement should be limited to two times the MBW Unit depth (front face to back face) to assure construction and long-term stability.
6. The top layer of reinforcement shall have a maximum spacing of 16 inches (0.40 m) from the top of the final MBW Unit row.

f. Placement of Reinforced Granular Backfill Material:

SPECIAL PROVISION

**SPECIFICATION 990 -
MECHANICALLY STABILIZED EARTH (MSE) RETAINING WALL SYSTEM**

1. The Reinforced Granular Backfill Material shall closely follow the erection of each course of facing unit. The reinforced material shall be placed in such a manner as to avoid any damage or disturbance of the wall materials or misalignment of the facing units or reinforcing elements.
2. At each reinforcement level, the reinforced granular backfill material shall be placed to the level of the connection. The reinforced granular backfill material placement methods near the facing shall assure that no voids exist directly beneath the reinforcing element.
3. For walls with MBW Facing Units, the backfill shall not be advanced more than the height of a modular block unit until the drainage fill, core fill and all fill in all openings within the blocks at that level have been placed. The filled units shall be swept clean of all debris before installing the next level of units and/or placing the geogrid materials.
4. The maximum lift thickness before compaction shall not exceed 8 inches (200 mm). The Contractor shall decrease this lift thickness, if necessary, to obtain the specified density.
5. For geosynthetic reinforcements, the fill shall be spread by moving the machinery parallel to or away from the wall facing and in such a manner that the geosynthetic remains taut. Construction equipment shall not operate directly on the geosynthetic. A minimum fill thickness of 6 inches (150 mm) over the geosynthetic shall be required prior to operation of vehicles. Sudden braking and sharp turning shall be avoided.
6. For metallic reinforcements, the fill shall be spread by moving the machinery parallel to or away from the wall facing and in such a manner that the steel reinforcement remains normal to the face of the wall. Construction equipment shall not operate directly on the metallic reinforcement. A minimum fill thickness of 3 inches (76 mm) over the metallic reinforcement shall be required prior to operation of vehicles. Sudden braking and sharp turning shall be avoided.
7. Any additional backfill material required between the projected plane of the geosynthetic reinforcement and cut-slope surface shall comply with the requirements of Reinforced Granular Backfill Material of this specification.

g. Compaction of Reinforced Granular Backfill Material:

SPECIAL PROVISION

SPECIFICATION 990 - MECHANICALLY STABILIZED EARTH (MSE) RETAINING WALL SYSTEM

1. The reinforced granular backfill material, complying with the gradation requirements of this specification shall be compacted with the following method:
 - i. Using a vibratory roller with a weight between 6 to 10 tons. Density requirements will not apply to compaction of the reinforced fill due to the coarse gradation size.
 - ii. Two roller passes of a vibratory roller having a minimum dynamic force of 6,000 pounds impact per vibration and a minimum frequency of 1,000 vibrations per minute. Operate vibratory roller at speeds less than 3 feet per second.
 - iii. Backfill within 3 feet (0.91 m) of the wall face shall be compacted utilizing a hand operated vibratory plate.

h. Compaction of Retained Backfill Material:

1. Retained backfill material shall be compacted conforming to the requirements article 203-3.05 of Specification 203 –.

990-3.11 Reinforced Concrete Cap – The Reinforced Concrete Cap shall be installed along the top facing units of the MSE Retaining Wall System as shown on plans and approved shop drawings. A bond breaker and expansion joint materials shall be placed between the top wall units and the reinforced concrete cap.

990-4 METHOD OF MEASUREMENTS

990-4.01 The construction of the Mechanically Stabilized Earth (MSE) Retaining Wall System will be measured by the square meter of wall surface area completed and accepted by the Engineer. The area will be bounded by the top elevation of the concrete leveling pad to the top elevation of the MSE Retaining Wall Facing Units, and the length of wall, as determined by field measurements. Any materials which become damaged during the MSE Retaining Wall System installation, or any misalignment or distortion of the wall facing units shall be removed and replaced by the Contractor as a subsidiary obligation

990-4.02 The unit of measurement for the MSE Retaining Wall System shall include:

- a. Construction of the Concrete Leveling Pad.
- b. Furnishing and installing and/or erecting all elements required by the MSE Retaining Wall System including but not limited to facing elements, soil

SPECIAL PROVISION

SPECIFICATION 990 - MECHANICALLY STABILIZED EARTH (MSE) RETAINING WALL SYSTEM

reinforcement, connecting devices, joint filler, bearing pads, geotextile filter, reinforced granular backfill material, subsurface drainage, penetrations such as pipes and other utilities, and any other MSE Retaining Wall System incidentals.

- c. All costs including any other material, labor, machinery, temporary construction aids (e.g., wedges, clamps, etc.), engineering cost related to design, shop drawings, submittals, construction procedures, quality control/quality assurance and monitoring by the Manufacturer/Supplier's representative related to the construction of the MSE Retaining Wall System.

990-4.03 Any excavation required for the construction of the MSE Retaining Wall System will be measured and paid under the provisions of Specification 206 - Excavation for Structures.

990-4.04 Any backfill required between the projected plane of the geosynthetic reinforcement and cut-slope surface will not be measured directly for payment but shall be considered a subsidiary obligation.

990-4.05 Foundation fill required for replacing any foundation soils found to be unsuitable will be measured and paid under the provisions of Specification 207 – Foundation Fill.

990-4.06 Any subsurface drainage or underdrain required to be installed as provided by plans or approved shop drawings shall be considered as a subsidiary obligation under the MSE Retaining Wall System pay item.

990-4.07 Reinforced Concrete Cap will be measured by the linear meter, to the nearest tenth of a cap completed and accepted. This shall include all required incidentals of the reinforced concrete cap, including bond breaker and expansion joints as shown on plans and approved shop drawings.

990-5 BASIS OF PAYMENT

990-5.01 Mechanically Stabilized Earth (MSE) Retaining Wall System, measured as provided above, will be paid for at the contract unit price per unit of measurement as provided below. Such price and payment shall constitute full compensation for all labor, supervision, transportation, materials, equipment, engineering, QC/QA and all incidentals required for the construction and erection of the system, to the lines and grades shown on the plans, as required by these specifications and approved by the Engineer.

SPECIAL PROVISION

**SPECIFICATION 990 -
MECHANICALLY STABILIZED EARTH (MSE) RETAINING WALL SYSTEM**

990-5.02 Payment for reinforced concrete cap will be made in accordance with the provisions of this Specification 990- Mechanically Stabilized Earth (MSE) Retaining Wall System

990-5.03 Payment will be made under:

<u>Pay Item</u>	<u>Pay Unit</u>
Mechanically Stabilized Earth (MSE) Retaining Wall System.....	Square Meter
Reinforced Concrete Cap.....	Linear Meter