

SECTION 548 RETAINING WALL SYSTEMS

548-1 Description.

Construct permanent and temporary retaining wall systems in accordance with this Section and in conformance with the lines, grades, design, and dimensions shown in the Contract Documents or established by the Engineer. The wall system chosen must be included in the Design Standards and listed as an alternate in the Contract Documents. Sheet pile walls and Cast-In-Place walls are not included in this specification. All other wall systems used to cut back existing slopes are paid for under the same pay item numbers shown in the Basis of Payment Article of this Specification. Construct all walls of a specific type (MSE (Mechanically Stabilized Earth), counterfort, etc) using the same wall system and supplier. If different types of wall systems must be used in a manner that causes one wall to interact with or influence another wall, coordinate the detailing of these areas of interaction/influence with the assistance of the Specialty Engineer.

548-2 Materials.

Purchase the precast components, soil reinforcement, attachment devices, joint filler, filter fabric, and all necessary incidentals from the wall supplier chosen.

548-2.1 Concrete: Ensure that concrete utilized for wall components is as specified in the Contract Documents and is consistent with the concrete class, environmental classification and admixture requirements for durability as stated in the Contract Documents. Produce and supply concrete for all wall components meeting the requirements of Section 346. Produce and supply concrete for the leveling pad meeting the requirements of Section 347. Assume responsibility for performance of all testing required by Section 346. Use Department approved mix designs.

548-2.2 Reinforcing Steel: Meet the requirements of Section 931 utilizing Grade 420 (Black) steel.

548-2.3 Soil Reinforcement: For walls utilizing soil reinforcement, use reinforcement consisting of steel wire mesh, metal strips or structural geosynthetics as required for the wall system chosen.

Use steel wire mesh and embedded loops shop fabricated from cold drawn steel wire meeting the minimum requirements of ASTM A 82, and weld into the finished mesh fabric in accordance with ASTM A 185. Use steel strips hot rolled from bars to the required shape and dimensions with physical and mechanical properties meeting ASTM A 572 [ASTM A 572M] Grade 65 [450] or as shown in the Contract Documents. Use shop-fabricated hot rolled steel tie straps meeting the minimum requirements of ASTM A 570 [ASTM A 570M], Grade 50 [345], or as shown in the Contract Documents.

Ensure that steel reinforcing strips, tie strips, reinforcing mesh and connectors used in permanent walls are galvanized in accordance with ASTM A 123 [ASTM A 123M] or ASTM A 153 [ASTM A 153M], as applicable.

Use structural geosynthetics made of polypropylene, select high density polyethylene or high-tenacity polyester fibers having cross-sections sufficient to permit significant mechanical interlock with the soil/backfill. Use geosynthetics having a high tensile modulus in relation to the soil/backfill. Use geosynthetics having high resistance to deformation under sustained long term design load while in service and resistant to ultraviolet degradation, to damage under normal construction practices and to all forms of biological or chemical degradation normally encountered in the material being reinforced.

Store the geosynthetics in conditions above 20°F [-7°C] and not greater than 140°F [60°C]. Prevent mud, wet cement, epoxy, and like materials from coming into contact with and affixing to the geosynthetic material. Rolled geosynthetic may be laid flat or stood on end for storage. Cover the geosynthetic and protect from sunlight prior to placement in the wall system.

Carefully inspect all reinforcement, steel and geosynthetics to ensure they are the proper size and free from defects that may impair their strength and durability.

548-2.4 Attachment Devices: Use soil reinforcement attachment devices as required by the wall system chosen.

548-2.5 Joint Materials and Filter Fabrics:

548-2.5.1 Horizontal Joint Filler: Use elastomeric or polymeric pads/fillers in all horizontal joints between precast components as recommended by the wall manufacturer. Ensure that the pads are of sufficient size and hardness to limit vertical stresses on the pad and concrete surface and to prevent concrete to concrete contact at the joints.

548-2.5.2 Joint Covers: Cover joints and other wall openings with geotextile fabric meeting the requirements of Section 985 and Type D-5 of the Design Standards, Index No. 199. Apply an adhesive approved by the Engineer to the back of the precast component for attachment of the fabric material.

548-2.5.3 Alignment Pins: Ensure that pins used to align the precast components during construction are of the size, shape and material required for the wall system chosen.

548-2.6 Backfill Material: Meet the requirements of Sections 105, and 120 except as noted within this Section. In addition, Provide certification to the Engineer that the following requirements have been met. Ensure that all backfill material used in the retaining wall volume is free draining and meets the requirements of this Section. Have the backfill material tested by a Department approved independent testing laboratory prior to placement. The retaining wall volume is defined to extend from the top of the leveling pad or footing, or bottom of walls which do not have footing or leveling pads, to the finish grade line and from the face of the wall to a vertical plane passing through the end of the extreme wall component (straps, counterforts, etc.) plus 1 foot [300 mm].

For constructing the retaining wall volume, do not use backfill material containing more than 2.0% by weight of organic material, as determined by FM 1-T 267 and by averaging the test results for three randomly selected samples from each stratum or stockpile of a particular material. If an individual test value of the three samples exceeds 3%, the stratum or stockpile will not be suitable for constructing the retaining wall volume.

Ensure that the plasticity index as determined by FM 1-T 090 does not exceed six and the liquid limit as determined by FM 1-T 089 is less than 15. The pH, as determined by FM 5-550, shall not be lower than five and not higher than ten, unless approved otherwise by the Engineer, as follows: For walls utilizing non-metallic soil reinforcement, the Engineer may approve using a backfill with a pH value between three and ten, if no metallic structures, such as metallic pipes, are placed within the backfill. Do not use backfill with a pH lower than three or higher than ten.

Use backfill for walls using soil reinforcements that meets the following gradation limits determined in accordance with FM 1-T 027 and FM 1-T 011:

Sieve Size		Percent Passing
3 1/2 inches	[90 mm]	100
3/4 inch	[19.0 mm]	70-100
No. 4	[4.75 mm]	30-100
No. 40	[425 µm]	15-100
No. 100	[150 µm]	5-65
No. 200	[75 µm]	0-15

In addition, for permanent walls utilizing metallic soil reinforcement, use backfill that meets the following electro-chemical test criteria for determining corrosiveness:

Criteria	Test Method
Resistivity: > 30 Ω -m	FM 5-551
Sulfate content: < 200 PPM	FM 5-553
Soluble chloride content < 100 PPM	FM 5-552

For walls not using soil reinforcement, use backfill that meets the following gradation limits determined in accordance with FM 1-T 027 and FM 1-T 011:

Sieve Size		Percent Passing
3 1/2 inches	[90 mm]	100
No. 200	[75 μ m]	0-15

548-3 Concrete Component Construction.

Construct concrete components in accordance with Section 400. Precast wall components are produced using certification acceptance; therefore, assume responsibility for performance of all testing and inspection required by Section 400 for the precast component construction. Perform all Quality Control and Assurance Testing using ACI qualified testing personnel. Perform compressive strength testing in a laboratory inspected by CCRL or CMEC, with all deficiencies corrected. The minimum time for form removal is 12 hours. Unless otherwise indicated in the Contract Documents, apply a Class 3 finish to the concrete surface for the front face, and roughly screed the rear face to eliminate open pockets of aggregate and surface distortions in excess of 1/4 inch [6 mm].

548-3.1 Curing: Cure concrete components in accordance with Section 400.

548-3.2 Tolerances: Meet the following manufactured tolerances:

1. Precast Component Dimensions: Lateral position of soil reinforcement attachment devices - within 1 inch [25 mm]. All other dimensions - within 3/16 inch [5 mm].
2. Precast Component Squareness: Angular distortion of the component shall not exceed 0.2 inches in 5 feet [5 mm in 1.5 m].
3. Precast Component Surface Finish: Surface defects on smooth formed surfaces measured on a length of 5 feet [1.5 m] shall not exceed more than 0.1 inch [3 mm]. Surface defects on textured finished surfaces measured on a length of 5 feet. [1.5 m] shall not exceed 5/16 inch [8 mm].

548-3.3 Marking of Precast Components: Clearly mark each precast components with the date of manufacture, the 346 concrete production LOT number and the piece-mark.

548-4 Rejection of Precast Components.

Precast wall components not meeting the quality standard of this Section and referenced Specifications will be rejected by the Department. In addition, any of the following defects will be sufficient cause for rejection by the Department:

1. Defects that indicate unsatisfactory molding.
2. Defects indicating honeycombed or open texture concrete.
3. Defects in the physical characteristics such as:
 - Signs of aggregate segregation;
 - Broken or cracked corners;
 - Soil reinforcement attachment devices improperly installed/damaged;
 - Lifting inserts not useable;
 - Exposed reinforcing steel;
 - Insufficient cover over reinforcing steel;
 - Cracks at the alignment pipe or pin;
 - Insufficient concrete compressive strength;

Precast Component thickness in excess of $\pm 3/16$ inch [± 5 mm] from that shown in the Contract Documents; or

Stained front face, due to excess form oil or other reasons.

If the face of the precast component is stained or discolored to the point of rejection, the stain or discoloration may be removed or a Department approved stain or a Class 5 finish may be applied to attain a uniform appearance for the entire structure, to the satisfaction of the Engineer.

548-5 Handling Storage and Shipping.

Handle, store and ship all components in a manner that prevents chipping, cracks, fractures, excessive bending stresses, mud, dirt and debris. Support precast components in storage on firm blocking located immediately adjacent to the attachment device.

548-6 Construction Requirements.

548-6.1 General: Due to the unique nature of the structure and concept, procure from the Wall Supplier fully detailed shop drawings, technical instructions, guidance in preconstruction activities and on-site technical assistance during construction. Closely follow any instructions from the Wall Supplier, unless otherwise directed by the Engineer. Submit a copy of any instructions from the Wall Supplier to the Engineer. Verify all pertinent retaining wall information (soil parameters, wall alignment, utility locations, conflicting structures) prior to the Wall Supplier finalizing shop drawings. Bring any conflicts not shown in the Contract Documents to the Engineer's attention.

548-6.2 Wall Excavation: Excavate to the limits shown in the Contract Documents and in conformance with Section 125.

548-6.3 Foundation Preparation: Grade the foundation for the structure level for a width equal to or exceeding the limits of the retaining wall volume or as shown in the Contract Documents. Prepare the foundation in conformance with Section 125.

In addition to the compaction requirements of Section 125, compact the graded area with an appropriate vibratory roller weighing a minimum of 8 tons [7 metric tons] for at least five passes or as directed by the Department's District Geotechnical Engineer. Remove and replace any soft or loose foundation subsoils which, are incapable of sustaining the required compaction to the Engineer's satisfaction.

For permanent MSE wall systems, provide an unreinforced concrete leveling pad as shown in the Contract Documents. Cure the leveling pad a minimum of 12 hours before placement of precast wall components.

548-6.4 Wall Erection: Assemble, connect and support wall components as recommended by the Wall Supplier. As backfill material is placed behind the wall face, maintain the wall in the vertical position or slightly battered into the backfill to provide a final vertical alignment (by means of bracing, temporary wooden wedges placed in the joint at the junction of the two adjacent precast components on the external side of the wall or other alignment aids). Remove wooden wedges as soon as the precast component above the wedged precast component is completely erected and backfilled. External bracing is required for the initial lift of MSE systems.

Place soil reinforcement normal to the face of the wall, unless otherwise shown in the Contract Documents or directed by the Engineer. Prior to placement of the reinforcement, compact the backfill in accordance with 548-6.5.

548-6.4.1 Tolerances for Permanent Walls: Ensure that vertical tolerances (plumbness) and horizontal alignment tolerances do not exceed $3/4$ inch [20 mm] when measured with a 10 foot [3.048 m] straight edge. The maximum allowable offset in the joint between precast components is $3/4$ inch [20 mm]. The final overall vertical tolerance of the completed wall (plumbness from top to bottom) shall not exceed $1/2$ inch per 10 feet [5 mm per meter] of wall height. Horizontal and vertical joints between precast components shall not be less than $1/2$ inch [13 mm] or more than $1 1/4$ inch [30 mm]. Walls which

do not meet these tolerances will not be accepted by the Department and must be removed and reconstructed at no cost to the Department.

548-6.4.2 Tolerances for Temporary Walls: Ensure that vertical tolerances (plumbness) and horizontal alignment tolerances do not exceed 3 inches [75 mm] when measured with a 10 foot [3.048 m] straight edge. The final overall vertical tolerance of the completed wall (plumbness from top to bottom) shall not exceed 1 inch per 3 feet [13 mm per meter] of wall height, not to exceed a total of 6 inches [150 mm]. Walls which do not meet these tolerances will not be accepted by the Department and must be removed and reconstructed at no cost to the Department.

548-6.5 Backfill Placement: Perform work in accordance with an approved Quality Control Plan (QCP) meeting the requirements of 6-8. A LOT is defined as a single lift of finished embankment not to exceed 500 feet [150 m] in length. Isolated compaction operations will be considered as separate LOTs. For multiple phase construction, a LOT will not extend beyond the limits of the phase.

Place the backfill closely following the erection of each course of precast components or soil reinforcement layers and spread by moving the machinery parallel to the wall face. Do not allow equipment heavier than 8 tons [7.5 metric tons] closer than 3 feet [1 m] behind the wall face. Place backfill in a manner to avoid any damage or disturbance to the wall materials or misalignment of the facing materials. Remove and replace any wall materials which become damaged or disturbed during backfill placement at no cost to the Department, or correct as directed by the Engineer. Remove and reconstruct any misalignment or distortion of the wall facing due to placement of backfill outside the limits of this specification at no cost to the Department.

Sheepfoot, grid rollers or other types of equipment employing a foot are not allowed. Achieve compaction within 3 feet [1 m] of the back of the wall face using a power operated roller or plate weighing less than 1,000 lbs [450 kg]. At a distance greater than 3 feet [1 m] from the back of the wall, a vibratory roller may be used, provided that the frequency and amplitude combined with bulk weight of the roller has performed satisfactorily at a trial section of the same type of wall. A smooth wheel or rubber tire roller is considered adequate. Ensure that the maximum lift thickness after compaction does not exceed 6 inches [150 mm]. Decrease the lift thickness if necessary, to obtain specified density.

Perform backfill compaction in a way that the compactor moves in a direction parallel to the wall face and proceeds from a distance not less than 3 feet [1 m] behind the wall face toward the end of the soil reinforcement element.

Ensure that the moisture content of the backfill material prior to and during compaction is uniformly distributed throughout each layer of material. Use backfill material having a placement moisture content at the dry side of the Optimum Moisture content. To achieve the required compaction moisture content, use water that meets the requirements of Section 923. Do not use saltwater. Do not transport excessively moist backfill materials to the site for any reason. The Engineer will determine the Optimum Moisture Content in accordance with FM 5-521.

At the end of each day's operation, shape the last level of backfill to permit runoff of rainwater away from the wall face or provide a positive means of controlling run off away from the wall such as temporary pipe, etc.

548-7 Acceptance Program.

548-7.1 General Requirements: Meet the requirements of 120-10.1 except delete the requirement of 120-10.1.4.1, 120-10.1.6 and 120-10.2.

548-7.2 Maximum Density Determination: Determine a minimum Quality Control (QC) density of 100% of the maximum density in accordance with FM 1 T-180.

548-7.3 Density Testing Requirements: Ensure compliance with the requirements of nuclear density testing in accordance with FM 1-T 238. Determine the in-place moisture content for each density test. Use FM 1-T 238, FM 5-507 (Determination of Moisture Content by Means of a Calcium Carbide

Gas Pressure Moisture Tester), or FM 5-535 (Laboratory Determination of Moisture Content of Granular Soils By Use of a Microwave Oven) for moisture determination.

Perform these tests at a minimum frequency of one set of tests per LOT. One set of tests is defined as a density test for the fill within 3 ft [1 m] behind the wall face and another density test for the fill beyond 3 feet [1 m] behind the wall face.

Determine test locations including stations and offsets, using the random number generator provided by the Engineer. Do not use note pads or work sheets to record data for later transfer to the density log book. Notify the Engineer upon successful completion of QC testing on each LOT.

548-7.4 Acceptance Criteria: Obtain a minimum density of 90% of the maximum dry density as determined by FM 1 T-180 within 3 ft [1 m] behind the wall face and obtain a minimum density of 95% of the maximum dry density as determined by FM 1 T-180 from beyond 3 feet [1 m] behind the wall face.

548-7.5 Frequency: Conduct sampling and testing at a minimum frequency listed in the table below. The Engineer will perform Verification sampling and tests at a minimum frequency listed in the table below.

Test Name	Quality Control	Verification
Maximum Density	One per soil type	One per soil type
Density	One set of tests per LOT per Section.	One set of tests per four LOTs for each type of QC test.

548-8 Certification.

Furnish a copy of all test reports which are necessary to document compliance with the Specifications, at least ten days prior to wall construction.

Also furnish the Engineer a Certificate of Compliance certifying that the retaining wall materials, backfill and construction practices comply with this Specification.

Acceptance of furnished material will be based on the Certificate of Compliance, accompanying test reports, and visual inspection by the Engineer.

548-9 Method of Measurement.

The quantity to be paid for will be the plan quantity, in square feet [square meters], completed and accepted, of the area bounded by the top of the coping, the top of the leveling pad, top of structural footings, bottom of walls which do not have footings or leveling pads, and the beginning and end wall limits as shown on the wall control drawings.

548-10 Basis of Payment.

Price and payment will be full compensation for all work specified in this Section, including the design of the wall system, excavation required specifically for wall construction below the normal roadway template, soil reinforcement, leveling pad, footings, copings, fabric material, horizontal joint materials, alignment pins, repairs, labor, equipment, and other materials necessary to complete the wall in an acceptable manner as shown on the Contract drawings. The cost of granular fill for the normal roadway template will be included in the cost of embankment or borrow excavation, as applicable.

Payment will be made under:

- Item No. 548-12- Retaining Wall System (Permanent) - per square foot.
- Item No. 2548-12- Retaining Wall System (Permanent) - per square meter.
- Item No. 548-13- Retaining Wall System (Temporary) - per square foot.
- Item No. 2548-13- Retaining Wall System (Temporary) - per square meter.