Section 2432. Mechanically Stabilized Earth (MSE) Retaining Wall

2432.01 DESCRIPTION.

Construct mechanically stabilized earth (MSE) retaining walls according to this specification and in reasonably close conformity with the lines, grades, design, and dimensions shown in the contract documents or established by the Engineer. MSE walls are defined as large panel retaining wall systems which use mesh or strips in the soil backfill material behind a concrete wall facing to limit backfill material stresses by reinforcing the soil structure.

2432.02 DESIGN AND MATERIALS.

A. Design

1. Wall Design Engineer.
The Wall Design Engineer shall be a Professional Engineer licensed in the State of Iowa.

2. Design Requirements.

a. Consideration is to be given to the internal stability of the wall mass. The wall is to be designed per Section 5, 'Retaining Walls', of the AASHTO Standard Specifications for Highway Bridges.

b. Design calculations are to include a summary of all design parameters used, including material types, strength values and assumed allowable soil bearing pressure, assumed load and loading combinations, and factor of safety parameters.

c. Earth reinforcing, and their connections to concrete panels, are to be designed for corrosion over the design life using the following electrochemical criteria:

Requirement	Test Method
Resistivity > 2,000 ohm-cm	AASHTO T 288
Chlorides < 200 ppm	AASHTO T 291
Sulfates < 300 ppm	AASHTO T 290

d. All appurtenances behind, in front of, under, mounted upon, or passing through the wall such as drainage structures, utilities, or other appurtenances shown in the contract documents are to be accounted for in the stability design of the wall.

e. Unless noted otherwise in the contract documents, a minimum cover of 4 feet (1.2 m) is to be provided from the top of the leveling pad to finish grade.

f. A special vertical corner element panel (to cover the joint of the panels that abut the corner and allow for independent movement of the abutting panels) is to be used where wall or wall sections intersect with an angle of 130 degrees or less on the backfill side. Corner elements are not to be formed by connecting standard facing panels that abut the acute corner.

g. The face panels are to be designed to accommodate differential settlement of 1 foot in 100 feet (0.3 m in 30 m). The spacing between adjacent panels is to be designed to be at least 3/4 inch (19 mm). Where shown in the contract documents, slip joints are to accommodate excessive differential settlement included.

3. Submittals.

a. MSE Supplier: For Interstate and Primary projects, provide the Office of Design, Soils Design Section with preliminary (non-structural) design calculations, which include estimated maximum applied (required) MSE wall bearing pressures, reinforcing strip or mesh lengths, and random backfill material requirements (if other than Class 10 backfill material), prior to preparation of their final MSE plans.

b. The Contractor: submit design computations and approved final MSE system construction drawings according to Article 1105.03. Ensure the drawings include all details, dimensions, and cross-sections necessary to construct the wall, and include (but are not limited to) the following:

1) An elevation sheet or sheets for each wall.

2) An elevation view of the wall which includes:

- The elevation at the top of the wall at all horizontal and vertical break points and at least every 15 feet (5 m) along the face of the wall,
- All steps in the leveling pads,
- The designation as to the type of panel,
- The length of soil reinforcing elements,

- The distance along the face of the wall to where changes in length of the soil reinforcing elements occur, and
- An indication of the final ground line and maximum calculated bearing pressures.

3) Details of the architectural treatment. Refer to the contract documents for details and nominal dimensions.

4) All panel details showing all dimensions necessary to construct the element, all reinforcing steel in the element, and the location of soil reinforcing connection devices embedded in the panels.

5) The details for connections between the concrete panel and the soil reinforcements.

6) A typical cross section or cross sections showing the elevation relationship between ground conditions and proposed grades.

7) General notes pertaining to design criteria and wall construction.

8) The details for diverting soil reinforcements around obstructions such as piles, catch basins, and other utilities.

9) Clearly indicated details for construction of walls around drainage facilities.

10) General location of subdrain and outlets of the internal drainage system.

B. Materials.

Install a wall system manufactured by a company on the approved manufacturer's list in Materials I.M. 445.03, Appendix A.

1. Concrete Panels.

a. Concrete.

1) Type I cement meeting requirements of Section 4101.

2) Cement content per cubic yard (cubic meter) of concrete for face panels and precast coping sections no less than 600 pounds (360 kg) nor more than 700 pounds (420 kg).

3) Concrete aggregates meeting the requirements of Sections 4110 and 4115. Class 3 durability crushed stone coarse aggregate. The use of gravel requires the Engineer's approval and is based on past history of deleterious and stain-producing material found in the aggregate source.

4) Air entrainment obtained by addition of an approved air-entraining agent. The air content of fresh, unvibrated concrete, as determined by AASHTO T 152, is to be 6.5% as a target value, with a maximum variation of ± 1.0%. When specified or authorized by the Engineer, approved admixtures for the purpose of improving workability or for retardation may be used according to the Engineer's instructions.

5) Obtain the Engineer's approval for the final mix design.

b. Compressive Strength.

1) Minimum compressive strengths for concrete reinforced face panels:

Strength prior to moving	Strength at 28 days
1800 psi (12.4 MPa)	4000 psi (27.6 MPa)

2) Acceptance of the concrete face panels with respect to compressive strength will be determined on a lot basis. The lot will consist of all production units (batches of concrete or panels) produced within a consecutive 7 day production period. Production units will be randomly selected according to the production day sample sizes of Table 2432.03-1 and tested for compressive strength. Perform compression tests on the test specimens according to Materials I.M. 315.

Table 2432.03-1: Production Day Samples

Production Day Quantities	Sample Size
35 cubic yards (27 m^3) or less (50 panels or less)	1
35-70 cubic yards (27-54 m^3) (50-100 panels)	2
70-100 cubic yards (54-81 m^3) (100-150 panels)	3
Over 100 cubic yards (81 m^3) (150 panels)	5

3) Cast a minimum of six test cylinders for each production unit sampled. Cure all of the specimens according to this specification.

4) Test two specimens at 7 days and two at 28 days. A test will be the average compressive strength of 2 cylinders.

5) Acceptance of the lot will be made:

- If all acceptance tests in a lot are greater than 4000 psi (27.6 MPa), or

- Provided no individual 28 day compressive-strength test result falls below 3500 psi (24.8 MPa), and the average 28 day compressive strength of all test results of the lot equals or exceeds the acceptance limits set forth in Table 2432.03-2.

6) Apply the acceptance limits of Table 2432.03-2 to core compressive strength test results.

Table 2432.03-2: Lot Acceptance Limits

Number of Lot Acceptance Tests	Average of all Lot Acceptance Tests Must Equal or Exceed these Limits
3-7	4000 psi + 0.33R* (27.6 MPa + 0.33R*)
8-15	4000 psi + 0.44R* (27.6 MPa + 0.44R*)
16+	4000 psi+ 0.46R* (27.6 MPa + 0.46R*)

* R is the range (the difference between the highest and lowest acceptance test result).

c. Reinforcement.

Epoxy coated steel meeting the requirements of Article 4151.03.

d. Casting.

1) Prior to casting, earth reinforcement connections or ties, PVC pipe, and lifting devices are to be set in place to the required dimensions and tolerances.

2) Panels are to be cast on a flat area, the front face of the panel at the bottom, the back face at the upper part. Reinforcement connection guides are to be set on the rear face. The concrete in each unit is to be placed without interruption and consolidated by use of an approved vibrator, supplemented by such hand-tamping as may be necessary to force the concrete into the corners of the forms and to prevent the formation of stone pockets or cleavage planes. Clear form oil from the same manufacturer is to be used throughout the casting operation.

e. Concrete Finish.

Uniform surface as designated on the formed front face. The rear face of the panel is to be roughly screeded to eliminate open pockets of aggregate and surface distortions.

f. Marking.

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

g. Fasteners.

Bolts and nuts for fasteners, where required, are to be of type and length recommended by the Wall Design Engineer; high strength, conforming to ASTM A 325 or equivalent, and galvanized.

h. Tolerances.

All units manufactured are to be within the following tolerances:

1) Lateral position of the strips within 1 inch (25 mm).

2) All dimensions within 1/4 inch (5 mm).

3) Angular distortion with regard to the height of the panel not to exceed 1/4 inch in 5 feet (5 mm in 1.5 m).

4) Surface defects on smooth-formed surfaces not to exceed 1/8 inch in 5 feet (2.5 mm in 1.5 m). On textured surfaces, surface defects not to exceed 5/16 inch in 5 feet (8 mm in 1.5 m).

i. Curing.

1) Panels are to be covered with wet burlap as soon as practical after casting, but not later than 30 minutes, and kept wet. Within two hours of the initial covering, water is to be applied to the burlap by means of a continuous, pressure-sprinkling system that is effective in keeping the burlap wet during the initial curing period. The initial curing period is to be continued until the minimum moving strength is obtained.

2) After the initial curing period is complete, panels may be moved from the casting beds to a secondary curing area and covered with one layer of wet burlap and one layer of 2 mil (50 µm) plastic, secured to retain curing moisture. Concrete face panels are not to be uncovered more than 30 minutes during the moving process. Curing is to be continued until the specified strength is obtained.

3) Steam curing procedures may be approved by the Engineer.

j. Removal of Forms.

Forms are to be left in place until they can be removed without damage to the unit.

k. Testing and Inspection.

1) Acceptability of the precast units will be determined on the basis of compression tests and visual inspection.

2) The precast units will be considered acceptable, regardless of age, when compression test results indicate the concrete will meet the specified 28-day strength. Panels will be considered acceptable for placement in the wall when 7-day strengths exceed 80% of 28-day requirements.

l. Rejection.

Units may be subject to rejection because of failure to meet any of the requirements specified above. In addition, any or all of the following defects may be sufficient cause for rejection:

1) Defects that indicate imperfect molding.

2) Defects indicating honeycombed or open-texture concrete.

m. Handling, Storage, and Shipping.

Handle, store, and ship all units in such a manner as to eliminate the danger of chipping, cracks, fractures, and excessive bending stresses. Store panels on firm blocking located immediately adjacent to earth reinforcing connections to avoid damage to support panels.

2. Leveling Pad.

This concrete may be any mix the supplier markets as having a nominal strength of 3500 psi (24.1 MPa).

3. Joint Materials.

a. Horizontal and Vertical Joints.

Cover horizontal and vertical joints between panels with a polyester fabric that meets requirements of Article 4196.01, B, 3, and is acceptable to the MSE wall company. Obtain the Engineer's approval for adhesives used to temporarily attach the fabric to the back of the facing panels.

b. Bearing or Filter Pads.

Ensure bearing and filter pads (where required) are of the quality and dimensions recommended by the MSE wall company. Obtain the Engineer's approval.

4. Subdrains.

a. Use one of the perforated, plastic pipes described in Article 4143.01, C. If the size is not designated, use a pipe of nominal diameter no less than 4 inches (100 mm) or more than 6 inches (150 mm).

b. Provide a Standard Road Plan RF-19F Type A outlet fitted with a Standard Road Plan RF-19E rodent guard.

5. Backfill Material.

a. Unless specified otherwise in the contract documents, furnish granular backfill material for the entire reinforced earth zone. Unless specified otherwise in the contract documents, furnish granular backfill material when identified as an MSE wall design requirement in the contract documents for core-outs, other remedial/ ground improvement location, or use behind the reinforced zone. Ensure the backfill material meets the requirements of Section 4133, except that the percent passing the No. 200 (75µm) sieve is not to exceed 5.0%.

b. Use backfill material meeting the following criteria for electrochemical requirements:

Requirement	Test Method
Resistivity > 3000 ohm-cm	AASHTO T 288
pH range 5 to 10	AASHTO T 289
Chlorides < 100 ppm	AASHTO T 291
Sulfates < 200 ppm	AASHTO T 290
Organic content < 1%	AASHTO T 267

c. The Engineer will take two samples from the source of the granular backfill material to determine the electrochemical levels. Obtain the Engineer's approval for the source of backfill material prior to placing.

6. Earth Reinforcing.

Carefully inspect all reinforcement to ensure it is true to size and free from defects that may impair its strength and durability.

a. Reinforcing and Tie Strip.

1. Tie strips shall be shop-fabricated from hot-rolled steel conforming to the minimum requirements of ASTM A 570, Grade 50, or equivalent. Galvanization shall comply with the minimum requirements of ASTM A 123 or equivalent.

2. Reinforcing strips shall be hot rolled from bars to the required shape and dimensions. Physical and mechanical properties shall comply with ASTM A 572, Grade 65, or equivalent. Galvanization shall comply with ASTM A 123. Strips shall be cut to lengths and tolerances shown on the plans or recommended. Holes for bolts shall be punched in the locations shown.

b. Reinforced Mesh

Prefabricated from smooth bars meeting the requirements of ASTM A 82 and A 185. Reinforcing mesh shall be galvanized according to ASTM A 123. Mesh connectors are to be galvanized according to ASTM A 153. Mesh is to be cut to lengths and tolerances shown in the contract documents.

2432.03 CONSTRUCTION.

A. Construction Supervision.

1. MSE units and reinforcement material suppliers shall provide a qualified and experienced representative on site at beginning of wall construction for up to 3 working days at no additional cost to the Contracting Authority.

2. The Contractor's field construction supervisor shall have demonstrated experience and be qualified to direct all work at the site.

B. Excavation.

Comply with the limits and construction stages shown on the contract documents. Prior to start of MSE wall construction, complete and obtain approval for core-outs or other remedial/ground improvement procedures identified in the construction drawing. Temporary or other excavation lines shown or depicted in the contract documents are for right of way, quantity calculation, and/or other design purposes only.

C. Foundation Soil Preparation.

Grade the foundation for the structure level for a width equal to or exceeding the length of reinforcing mesh or strips, unless shown otherwise in the contract documents. Prior to wall construction, compact the foundation with a smooth-wheeled, vibratory roller.

D. Leveling Pad.

At each panel leveling pad, place an unreinforced concrete leveling pad provided as shown in the contract documents. Cure the footing for a minimum of 24 hours before wall panel placement.

E. Wall Erection.

1. Panels.

For erection, handle the panels using a lifting device set into the upper edge of the panels. Place the panels in successive horizontal lifts in the proper sequence as backfill material placement proceeds. As backfill material is placed behind a panel, maintain the panels in position by means of temporary wooden wedges placed in the joint at the junction of the two adjacent panels on the external side of the wall. External bracing may also be required for the initial lift. Ensure vertical tolerances and horizontal alignment tolerance do not exceed 3/4 inch (19 mm) when measured along a 10 foot (3 m) straight edge. Limit offsets in panel joints to 3/4 inch (19 mm) or less. Ensure the overall vertical tolerance of the wall does not exceed 1/2 inch per 10 feet (12.5 mm per 3 m) of wall height.

2. Coping.

Place the coping as shown in the contract documents. Mix, cast, and cure precast coping units with the same concrete mixture and in the same manner as used for construction of the panels. Cast-in-place coping may be constructed in the same manner or Class C structural concrete may be used; however, use aggregates meeting the same quality requirements as are specified in Article 2432.02, B, 1.

F. Subdrains.

1. Install the subdrains behind the bottom course of panels in direct contact with the granular backfill material. Install a second subdrain at the base of the temporary excavation backslope, behind the reinforced earth zone, and at an elevation similar to the subdrain behind the bottom course of panels. Place vertical pipes (if required) as shown in the contract documents. Install the subdrain as shown in the contract documents to maintain gravity flow of water to outside of the reinforced earth zone. The subdrain should outlet into a storm sewer access or along a slope at an elevation lower than the lowest point of the pipe within the reinforced earth zone.

2. The contract documents may require additional subdrain at the base of the granular backfill material in a core-out, if used.

3. Place porous backfill material meeting the requirements of Section 4131 around the subdrain to a minimum cover of 3 inches (75 mm).

G. Backfill Placement.

1. Place backfill material in a manner to closely follow the erection of each lift of panels. At each level for earth reinforcing, roughly level the backfill material before placing and connecting reinforcement. Place reinforcing normal to the face of the wall. Closely follow panel erection with placement of lifts. Decrease this lift thickness, if necessary, to obtain the specified density.

2. At the end of each day's operations, shape the last level of backfill material so as to permit runoff of rainwater away from the wall face.

3. Compact backfill material according to Article 2107.03, H. Place granular backfill material in the reinforced zone and behind the reinforced zone as shown in the contract documents in maximum 8 inch (200 mm) lifts. Compact to a minimum 95% of Standard Proctor density (ASTM D 698). Ensure moisture limits are between 1% under optimum moisture to not more than 2% over optimum moisture content. Perform backfill material compaction without disturbing or distorting earth reinforcing and panels. Do not use tamping-type rollers or other rollers which damage the reinforcing. In a 3 foot (1 meter) wide strip adjacent to the backside of the wall, use light mechanical tampers to achieve compaction. Compaction within this strip will not be subjected to density testing.

4. Compact granular backfill material and/or other materials placed in a core-out or other remedial/ground improvement location to a minimum of 98% of Standard Proctor density or as otherwise defined in the contract documents.

H. Earth Reinforcing Placement.
Place tie strips or mesh in horizontal layers as detailed in the contract documents. When tie strips or mesh can not be placed as detailed in the contract documents, submit a modified placement plan as recommended by the Wall Design Engineer for approval by the Engineer.

I. Surface Water Control
The cross sections in the contract documents will show excavation for any temporary backslope behind the reinforced earth zone. Protect the backslope from surface water which will affect stability of the backslope. Provide positive control and discharge for surface water in the area behind the backslope. If a gravity outlet is available, drain the bases of core-out excavations by temporary trench outlets or subdrains until granular backfill material is installed in the core-out.

2432.04 METHOD OF MEASUREMENT.
The work involved in construction of Mechanically Stabilized Earth Retaining Walls will be measured as follows:

A. Mechanically Stabilized Earth Retaining Wall.
The Engineer will measure the area of Mechanically Stabilized Earth Retaining Wall in square feet (square meters), from measurements of the front face of the wall in place. The height will be measured from the top of the leveling pad to the top of the wall, including coping.

B. Granular Backfill Material.
The quantity of Granular Backfill Material, in tons or cubic yards (megagrams or cubic meters), that is placed in the reinforced earth zone; identified as an MSE wall design requirement in the contract documents for any core-out or other remedial/ground improvement location; or placed in the temporary excavation zone behind the reinforced earth zone as shown in the contract documents, will be measured in tons or cubic yards (megagrams or cubic meters).

C. Excavation.
Excavation for preparing the reinforced earth zone for construction of the wall and all core-outs or other remediations/ground improvement areas included in the contract documents will be classed and measured according to Section 2102.

2432.05 BASIS OF PAYMENT.
Payment for construction of Mechanically Stabilized Earth Retaining Walls, satisfactorily placed, will be as follows:

A. Mechanically Stabilized Earth Retaining Wall.
For the number of square feet (square meters) of Mechanically Stabilized Earth Retaining Wall constructed, the Contractor will be paid the contract unit price per square foot (square meter). This payment is full compensation for furnishing and erecting the MSE retaining wall including the design, foundation preparation, leveling pad, panels, coping, earth reinforcement placement, and subdrains according to the contract documents. Subdrains within core-out areas, if required in the contract documents, will be measured and paid for separately.

B. Granular Backfill Material.

1. For Contractor furnished Granular Backfill Material for the reinforced earth zone; any core-outs or other remedial/ground improvement locations; and placed in the temporary excavation zone behind the reinforced earth zone as shown in the contract documents, the Contractor will be paid for the quantity of material furnished, hauled, actually placed, and compacted for the contract unit price per ton or cubic yard (megagram or cubic meter) up to the contract quantity.

2. If the slope shown for the temporary excavation zone in the contract documents is not adequate for safety, provide written notification to the Engineer, including a copy of a slope stability analysis, and identification of the additional quantity of Granular Backfill Material that will be needed, before the work begins. The slope stability analysis is to be done by a Professional Engineer licensed in the State of Iowa (at no addition cost to the Contracting Authority). If approved by the Engineer, the additional quantity for Granular Backfill Material will be adjusted according to Article 1109.03, A.

C. Excavation.

1. For the quantity of each class of excavation for preparing the reinforced earth zone and all core-outs or other remediation/ground improvement areas included in the contract documents for construction of the wall, the Contractor will be paid as provided in Article 2102.05, A, 1. This will normally be included for payment with other excavation required by the contract documents.

2. If the slope shown for the temporary excavation zone in the contract documents is not adequate for safety, provide written notification to the Engineer, including a copy of a slope stability analysis, and identification of the additional quantity of excavation that will be needed, before the work begins. The slope stability analysis shall be done by a Professional Engineer licensed in the State of Iowa (at no additional cost to the Contracting Authority). If approved by the Engineer, the additional quantity for excavation will be adjusted according to Article 1109.03, A.