



**DEVELOPMENTAL SPECIFICATIONS
FOR
MECHANICALLY STABILIZED EARTH (MSE) RETAINING WALL**

**Effective Date
August 18, 2009**

THE STANDARD SPECIFICATIONS, SERIES 2001, ARE AMENDED BY THE FOLLOWING MODIFICATIONS AND ADDITIONS. THESE ARE DEVELOPMENTAL SPECIFICATIONS AND THEY SHALL PREVAIL OVER THOSE PUBLISHED IN THE STANDARD SPECIFICATIONS.

01105.01 DESCRIPTION.

This work consists of construction of mechanically stabilized earth (MSE) retaining walls in accordance with this specification and in reasonably close conformity with the lines, grades, design, and dimensions shown on the plans or established by the Engineer. MSE walls are defined as large panel retaining wall systems which use mesh or strips in the soil backfill behind a concrete wall facing to limit backfill stresses by reinforcing the soil structure.

01105.02 DESIGN.

A. Wall Design Engineer.

The wall design shall be performed by a Professional Engineer licensed in the State of Iowa that prepares and seals the design submittals as defined in this specification.

B. Design Requirements.

The design by the wall system supplier shall consider the internal stability of the wall mass. Wall design shall be as per Section 5, 'Retaining Walls', of the AASHTO Standard Specifications for Highway Bridges.

Design calculations shall 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.

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

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

All appurtenances behind, in front of, under, mounted upon, or passing through the wall such as drainage structures, utilities, or other appurtenances shown on the plans shall be accounted for in the stability design of the wall.

Unless otherwise noted on the plans, a minimum cover of 4 feet (1.2 m) shall be provided from the top of the leveling pad to finish grade.

Where wall or wall sections intersect with an angle of 130 degrees or less on the backfill side, a special vertical corner element panel shall be used. The corner element panels shall cover the joint of the panels that abut the corner, and allow for independent movement of the abutting panels. Corner elements shall not be formed by connecting standard facing panels that abut the acute corner.

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

C. Submittals.

For Interstate and Primary projects, the MSE supplier shall 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 requirements (if other than Class 10 backfill) prior to preparation of their final MSE plans.

The Contractor shall submit design computations and approved final MSE system construction drawings in accordance with Article 1105.03 of the Standard Specifications.

These construction drawings shall include all details, dimensions, and cross-sections necessary to construct the wall and shall include, but shall not be limited to the following:

1. An elevation sheet or sheets for each wall.
2. An elevation view of the wall which shall include 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 plans for details and nominal dimensions.
4. All panel details shall show 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.

01105.03 MATERIALS

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

A. Concrete Panels.

1. Concrete.

Cement shall be Type I, meeting requirements of Section 4101 of the Standard Specifications.

Cement content per cubic yard (cubic meter) of concrete for face panels and precast coping sections shall be not less than 600 pounds (360 kg) nor more than 700 pounds (420 kg).

Concrete aggregates shall meet requirements of Sections 4110 and 4115 of the Standard Specifications. Coarse aggregate shall be Class 3 durability, as defined in Article 4115.04 of the Standard Specifications. The use of gravel is subject to approval by the Engineer, based on past history of deleterious and stain-producing material found in the aggregate source.

Air entrainment shall be obtained by addition of an approved air-entraining agent. The air content of fresh, unvibrated concrete, as determined by AASHTO T 152, shall be 6.5% as a target value, with a maximum variation of $\pm 1.0\%$. 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.

The final mix design is subject to the approval of the Engineer.

2. Compressive Strength.

The concrete in reinforced earth face panels shall have the following minimum compressive strength.

<u>Strength prior to moving</u>	<u>Strength at 28 days</u>
1800 psi (12.4 MPa)	4000 psi (27.6 MPa)

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 in accordance with the production day sample sizes of Table A and tested for compressive strength. Compression tests shall be made on the test specimens in accordance with Materials I.M. 315.

Table A

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

A minimum of four test cylinders shall be cast for each production unit sampled. All of the specimens shall be cured in accordance with this Developmental Specification.

Two specimens shall be tested at 7 days and 2 at 28 days. A test will be the average compressive strength of 2 cylinders.

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 B.

The acceptance limits of Table B shall also apply to core compressive strength test results.

Table B. 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.

3. Reinforcement.

Reinforcement steel shall be per Article 4151.03 of the Standard Specifications and shall also be epoxy coated per Article 4151.03, B.

4. Casting.

Earth reinforcement connections or ties, PVC pipe, and lifting devices shall be set in place to the required dimensions and tolerances, prior to casting.

The panels shall 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 shall be set on the rear face. The concrete in each unit shall be placed without interruption and shall be 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 of the same manufacturer shall be used throughout the casting operation.

5. Concrete Finish.

The formed front face shall have a uniform surface as designated. The rear face of the panel shall be roughly screeded to eliminate open pockets of aggregate and surface distortions.

6. Marking.

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

7. Fasteners.

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

8. Tolerances.

All units shall be manufactured within the following tolerances:

- a. Lateral position of the strips within 1 inch (25 mm)
- b. All dimensions within 1/4 inch (5 mm)
- c. Angular distortion with regard to the height of the panel shall not exceed 1/4 inch in 5 feet (5 mm in 1.5 m).
- d. Surface defects on smooth-formed surfaces shall not exceed 1/8 inch in 5 feet (2.5 mm in 1.5 m). On textured surfaces, surface defects shall not exceed 5/16 inch in 5 feet (8 mm in 1.5 m).

9. Curing.

As soon as practical after casting, but not later than 30 minutes, the panels shall be covered with wet burlap and kept wet. Within two hours of the initial covering, water shall 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 shall continue until the minimum moving strength is obtained.

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. The concrete face panels shall not be uncovered more than 30 minutes during the moving process. Curing shall continue until the specified strength is obtained.

Steam curing procedures may be approved by the Engineer.

10. Removal of Forms.

The forms shall remain in place until they can be removed without damage to the unit.

11. Testing and Inspection.

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

The precast units will be considered acceptable, regardless of age, when compression test results indicate the concrete will meet the specified 28-day strength. The Contractor or the Contractor's supplier shall furnish facilities and collaborate with the Engineer so that all necessary sampling and testing is done in an expeditious and satisfactory manner, subject to approval of the Engineer. Panels will be considered acceptable for placement in the wall when 7-day strengths exceed 80% of 28-day requirements.

12. 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:

- a. Defects that indicate imperfect molding.
- b. Defects indicating honeycombed or open-texture concrete.

13. Handling, Storage, and Shipping.

All units shall be handled, stored, and shipped in such a manner as to eliminate the danger of chipping, cracks, fractures, and excessive bending stresses. Panels in storage shall be supported on firm blocking located immediately adjacent to earth reinforcing connections to avoid damage.

B. Leveling Pad.

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

C. Joint Materials.

1. Horizontal and Vertical Joints.

Cover for horizontal and vertical joints between panels shall be a polyester fabric meeting requirements of Article 4196, C, of the Standard Specifications and acceptable to the MSE wall company. Adhesives used to temporarily attach the fabric to the back of the facing panels shall be subject to approval by the Engineer.

2. Bearing or Filter Pads.

Where required, bearing and filter pads shall be of the quality and dimensions recommended by the MSE wall company, subject to approval of the Engineer.

D. Subdrains.

Subdrains shall be perforated, plastic pipe of one of the types described in Article 4143.01, C, of the Standard Specifications. If the size is not designated, the nominal diameter shall be not less than 4 inches (100 mm) nor more than 6 inches (150 mm).

Standard Road Plan RF-19E Type A outlet shall be provided and fitted with a Standard Road Plan RF-19E rodent guard.

E. Backfill.

Granular Backfill material for the entire reinforced earth zone shall be furnished by the Contractor, unless otherwise specified in the contract documents. When identified as MSE wall design requirement in the contract documents, the granular backfill for any core-outs, other remedial/ ground improvement location, or behind the reinforced zone, shall be furnished by the Contractor unless otherwise specified in the contract documents. Contractor furnished Granular Backfill material shall meet the requirements of Section 4133 of the Standard Specifications, except that the % passing the No. 200 (75 micron) sieve shall not exceed 5.0%.

The backfill shall meet the following criteria for electrochemical requirements:

<u>Requirement</u>	<u>Test Method</u>
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

The Engineer will take two samples from the source of the granular backfill material to determine the electrochemical levels. The source of backfill shall be approved by the Engineer before placement.

F. Earth Reinforcing.

All reinforcing shall be carefully inspected to insure they are true to size and free from defects that may impair their strength and durability.

1. Reinforcing and Tie Strip.

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 conform to the minimum requirements of ASTM A 123 or equivalent. Reinforcing strips shall be hot rolled from bars to the required shape and dimensions. Their physical and mechanical properties shall conform to ASTM A 572, Grade 65, or equivalent. Galvanization shall conform to 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.

2. Reinforced Mesh

Reinforcing mesh shall be prefabricated from smooth bars meeting the requirements of ASTM A 82 and A 185. Reinforcing mesh shall be galvanized in accordance with ASTM A 123. The mesh connector shall be galvanized in accordance with ASTM A 153. The mesh shall be cut to lengths and tolerances shown on the plans or on the shop drawings.

01105.04 CONSTRUCTION**A. Construction Supervision.**

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

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

B. Excavation.

Excavation shall conform to the limits and construction stages shown on the contract documents. Any core-outs or other remedial/ground improvement procedures identified in the construction drawing shall be completed and approved prior to start of MSE wall construction. Temporary or other excavation lines shown or depicted in the construction drawings are for right of way, quantity calculation, and/or other design purposes only.

C. Foundation Soil Preparation.

The foundation for the structure shall be graded level for a width equal to or exceeding the length of reinforcing mesh or strips, unless otherwise shown on the construction drawings. Prior to wall construction, the foundation shall be compacted with a smooth-wheel, vibratory roller.

D. Leveling Pad.

At each panel leveling pad, an unreinforced concrete leveling pad shall be provided as shown on the construction drawings. The footing shall be cured a minimum of 24 hours before placement of wall panels.

E. Wall Erection.**1. Panels.**

For erection, panels are to be handled by means of a lifting device set into the upper edge of the panels. Panels should be placed in successive horizontal lifts in the proper sequence as backfill placement proceeds. As fill material is placed behind a panel, the panels shall be maintained 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. Vertical tolerances and horizontal alignment tolerance shall not exceed 3/4 inch (19 mm) when measured along a 10 foot (3 m) straight edge. The maximum allowable offset in any panel joint shall be 3/4 inch (19 mm). The overall vertical tolerance of the wall shall not exceed 1/2 inch per 10 feet (12.5 mm per 3 m) of wall height.

2. Coping.

The coping shall be placed as shown on the construction drawings. Precast coping units shall be mixed, cast, and cured 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, the aggregates shall meet the same quality requirements as are specified in Article 01048.03, A, 1.

F. Subdrains.

The subdrains shall be installed behind the bottom course of panels in direct contact with the granular backfill material. A second subdrain shall be installed 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. If required, vertical pipes shall be placed as shown on the plans. The subdrain shall be installed as shown in the construction drawings 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.

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

Porous backfill, in accordance with Section 4131 of the Standard Specifications, shall be placed around the subdrain to a minimum cover of 3 inches (75 mm).

G. Backfill Placement.

Backfill placement shall closely follow the erection of each lift of panels. At each level for earth reinforcing, backfill should be roughly leveled before placing and connecting reinforcement. Reinforcing shall be placed normal to the face of the wall. The placement of lifts shall closely follow panel erection. The Contractor shall decrease this lift thickness, if necessary, to obtain the specified density.

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

Backfill shall be compacted in accordance with Article 2107.08 of the Standard Specifications. The Granular Backfill in the reinforced zone and any Granular Backfill placed behind the reinforced zone shall be placed as shown in the construction drawings in maximum 8 inch (200 mm) lifts and compacted to a minimum 95% of standard Proctor density (ASTM D 698). The moisture limits shall be between 1% under optimum moisture to not more than 2% over optimum moisture content. Backfill compaction shall be accomplished without disturbance or distortion of earth reinforcing and panels. Tamping-type rollers or other rollers which damage the reinforcing shall not be used. The required compaction in a strip 3 feet (1 m) wide adjacent to the backside of the wall shall be achieved using light mechanical tampers; however, compaction within this strip will not be subjected to density testing.

Granular Backfill and/or other materials placed in a core-out or other remedial/ground improvement location shall be compacted to a minimum of 98% of Standard Proctor density or as otherwise defined in the construction documents.

H. Earth Reinforcing Placement.

Tie strips or mesh shall be placed in horizontal layers as detailed in the construction drawings. When tie strips or mesh can not be placed as detailed in the construction drawings, the Contractor shall 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. The backslope shall be protected from surface water which will

affect stability of the backslope. Positive control and discharge shall be provided for surface water in the area behind the backslope. If a gravity outlet is available, the base of any core-out excavation shall be drained by temporary trench outlet or subdrain until Granular Backfill is installed in the core-out.

01105.05 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 any core-outs or other remediations/ground improvement areas included in the contract documents will be classed and measured according to Section 2102 of the Standard Specifications.

01105.06 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 ~~yards~~ ~~feet~~ (square meters) of Mechanically Stabilized Earth Retaining Wall constructed, the Contractor will be paid the contract unit price per square ~~yard~~ ~~foot~~ (square meter). This payment shall be full compensation for furnishing and erecting the MSE retaining wall including the design, foundation preparation, leveling pad, panels, coping, earth reinforcement placement, and subdrains in accordance with 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.

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.

If the Contractor determines that the slope shown for the temporary excavation zone in the contract documents is not adequate for safety, they shall provide written notification to the Engineer, including a copy of a slope stability analysis, and identification of the additional quantity of Granular Backfill 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. The cost of the slope stability analysis shall be the responsibility of the Contractor. If approved by the Engineer, the additional quantity for Granular Backfill will be adjusted in accordance with Article 1109.03,A of the Standard Specifications.

C. Excavation.

For the quantity of each class of excavation for preparing the reinforced earth zone and any 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 2102.14, A, of the Standard Specifications. This will normally be included for payment with other excavation required by the contract documents.

If the Contractor determines that the slope shown for the temporary excavation zone in the contract documents is not adequate for safety, they shall 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. The cost of the slope stability analysis shall be the responsibility of the Contractor. If approved by the Engineer, the additional quantity for excavation will be adjusted in accordance with Article 1109.03,A of the Standard Specifications.