Mechanically Stabilized Earth (MSE) Wall Evaluations

Design Manual
Chapter 200
Geotechnical Design
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Mechanically Stabilized Earth (MSE) wall systems are retaining wall structures that function as gravity walls. MSE walls are defined as large panel retaining wall systems that use metallic/geosynthetic mesh or strips in the soil backfill material behind a concrete panel wall facing to limit backfill material stresses by reinforcing the soil structure. The Iowa DOT currently allows only metallic reinforcement in MSE walls. MSE wall systems are designed for the external stability of the wall system along with the internal stability of reinforced soil behind the wall face.

Walls are to be designed according the AASHTO LRFD Bridge Design Specifications (see Section 2432.02 of the Standard Specifications). The Soils Design Section is responsible for the External Stability evaluation (bearing capacity, sliding, overturning, settlement, and global stability). The wall designer/vendor is responsible for the Internal Stability (reinforcement strength and pullout).

MSE walls should not be used, or should be used only with caution and with full and complete evaluation of all factors, under the following circumstances:

- In areas where utilities aside from highway drainage will be constructed. Reinforcement elements must not be disrupted by placement of utility lines.
- In places where floodplain erosion (scour) may result in instability of the reinforced fill zones or the supporting leveling pads and/or footings.
- When reinforcing material may be exposed to surface or ground water contaminated with acid mine drainage, pollutants, or other environmental threats.

Geometrically complex MSE wall systems such as tiered walls (walls stacked on top of one another), back-to-back walls, or walls which have trapezoidal sections, should be evaluated on a case-by-case basis. Evaluation of such complex systems needs to include the evaluation of compound stability (compound failures passing both through the unreinforced and reinforced zones).

Quick Tips:

- External Stability evaluation (bearing capacity, sliding, overturning, settlement, and global stability) is evaluated by the Soils Design Section.
- Internal Stability (reinforcement strength and pullout) evaluation is performed by wall designer.
- Sufficient right-of-way is required to install soil reinforcement within the backfill materials. Additionally, the minimum reinforcement length is typically the greater of the following:
  - At least 8 feet, or
  - 80% of the wall height.

Project Data for MSE Wall Design

The project characteristics (alignment, surcharges, etc.) will influence the overall MSE wall design and construction, and must be identified by the wall designer/vendor. Some of the characteristics include:

- Surcharge loads from adjacent structures.
- Backslope and toe slope geometries (ditches, slopes).
- Right of way restrictions, utility easements, and excavation limits.
- Wetlands, streams (potential for scour).

- Backfill materials sources.
- Construction staging.

The MSE wall system must be designed to provide proper performance of adjacent roadways and structures. The MSE wall designer/vendor must identify performance criteria such as:

- Tolerable settlements for the MSE walls.
- Tolerable settlements of structures or property being retained.
- Impact of construction on adjacent structures or property.
- Long term maintenance needs and access.

Geotechnical Data for MSE Wall Design

For each of the MSE wall alignments, the site and subsurface conditions should be analyzed to identify areas of geotechnical concern, risk, or potential variability in subsurface conditions which may influence the technical feasibility, design, and/or construction or economic viability of the MSE wall system. The proposed wall alignments will be included within the S2 submittal (see Section 200B-2) and finalized within the S3 submittal (see Section 200B-3). The scope of geotechnical analyses that is required may vary with the wall type and configuration, but the analyses typically included are global stability, overturning and sliding, bearing capacity, and settlement. Subsurface information along the proposed wall alignments should be obtained according to Section 200C-1 and/or Section 200I-1.

Soils Design Section Predesign Process

The Soils Design Section is responsible for the evaluation of the MSE wall external stability (bearing, sliding, global stability, settlement, etc.) and analyzes proposed walls and their related project geometry in a pre-design process (in the design phase, prior to advertising for letting). These pre-design analyses are done because the final bearing capacity and other requirements for the wall are determined by the MSE vendor after letting and are not known until after letting. These analyses are performed to evaluate the need for ground improvement. If improvements are required, the type and quantity of ground improvement can be selected and included in the project bidding plans, reducing the potential for Extra Work Order items after letting when the wall vendor's plans are submitted. In these pre-design analyses, global stability and settlement are calculated by means and methods selected by the engineer of record. Calculations of wall loads and foundation stresses for bearing, sliding, and overturning are calculated by methods according to the latest version of the AASHTO LRFD Bridge Design Manual.

When ground improvement is determined necessary for one or more reasons, the actual or estimated areal extent and depth of the improvement are placed in plan and profile views on the project Q sheets (Section 1F-16) and/or SPS sheets (Section 1F-19). In the case of a core-out type of remediation, the areal extent and depth of excavation can be fully designed before plans are posted for letting. In the case of a contractor designed remediation, such as Intermediate Foundation Improvements (geopiers/aggregate piers or stone columns), the anticipated areal extent and depth of the proposed remediation are placed on the plans, and performance specifications for bearing resistance, global stability factor of safety, allowable settlement, and allowable differential settlement are provided in a project specific Special Provision. The ground improvement contractor/vendor designs the specifics of their system to meet the requirements of the Special Provisions, including the final areal extent, depth, and installation pattern. Initial coordination of this between the main contractor and the ground improvement contractor/vendor may occur prior to letting, but the contractor designed remediation is submitted to Iowa DOT after letting in conjunction with the vendor's MSE wall plans.

External Stability Evaluation

The Soils Design Section is responsible for the External Stability evaluation of MSE wall systems, which includes sliding, bearing capacity, overturning resistance, settlement, and global stability to the internal and external loads. Loads for external and internal stability are taken as specified in the AASHTO LRFD Bridge Design Specifications and should include the appropriate load factors for traffic surcharges. All

geotechnical parameters used in the evaluation of the MSE wall systems for evaluation and how they were developed should be clearly stated within the MSE wall calculation package. Engineering properties of soils should be according to Section 200E-1. The following summarizes the external stability evaluations:

Sliding

Sliding failure occurs if the force effects due to the horizontal component of loads exceed the more critical of either the factored shear resistance of the soils or the factored shear resistance at the interface between the soil and the foundation. The sliding resistance of the MSE wall system is evaluated under the Strength Limit load according to the AASHTO LRFD Bridge Design Specifications.

Bearing Resistance

Bearing pressures at the base of the wall system are computed using strength limit loads according to the AASHTO LRFD Bridge Design Specifications. The computed strength limit bearing pressure must be less than the factored bearing capacity of the soil, as determined from shear strength parameters established from data obtained in the geotechnical investigation.

Overturning

Overturning failure occurs if the force effects due to the horizontal component of loads exceed the sum of the MSE wall systems mass. The overturning resistance of the MSE wall system is evaluated under the strength limit load according to the AASHTO LRFD Bridge Design Specifications.

Global Stability

The global stability evaluation of the MSE wall configuration must be performed by the owner's geotechnical engineer during the plan development phase. The initial global stability evaluation will usually be started assuming uniform soil reinforcement lengths of at least 70 percent of the wall height, 0.7*H,* unless specified otherwise by the wall designer, or a minimum of length 8 feet. The global stability analysis assumes failure outside the reinforced zone. Compound stability evaluations are usually not performed for typical wall geometries.

Non-uniform reinforcement lengths may be used under the following circumstances:

- Lengthening the upper reinforcement layers above the 0.7*H* ratio to meet pullout, seismic, or impact loads.
- Lengthening the lower reinforcement layers to meet global stability requirements from global stability analysis.
- Shortening the bottom layers to less than 0.7*H* to reduce excavation requirements only if the wall is bearing on rock or other competent foundation soil.

Global stability of the MSE wall system should be evaluated for the various conditions outlined in Section 200F-1 at the Service I Load Combination with an appropriate resistance factor, ϕ (or minimum factor of safety). Since the slope stability evaluation is performed at the service limit state; the resistance factors are combined with a load factor of 1.0. Thus, resistance factors of 0.75 and 0.65 are equivalent to a safety factor of 1.3 and 1.5, respectively. The following factors of safety (resistance factors) are recommended for design of slopes.

- Take $\phi = 0.75$ if geotechnical parameters are well defined and the slope does not support or contain a structural element (bridge/roadway).
- Take $\phi = 0.65$ if geotechnical parameters are limited or if the slope supports or contains a structural element (bridge/roadway).

Settlement Evaluation

MSE wall design is to structurally accommodate the effects of total and differential settlement estimated for the project site, both longitudinally and in cross-section, as prescribed in the AASHTO

LRFD Specifications. The movement criteria outlined in Table 1 should be used to establish acceptable settlement criteria including proprietary walls designed using the AASHTO Standard Specifications for Highway Bridges (2002). For MSE walls with precast panel facings up to 75 ft^2 in area, follow AASHTO LRFD Specifications, Section 11.10.4 for limiting differential settlements. More stringent tolerances may be necessary to meet aesthetic requirements for the walls.

Table 1: Settlement criteria for MSE walls with modular (segmental) block facings.

total settlement	differential settlement over 100 ft	action
$\Delta H \leq 2$ in	$\Delta H_{100} \leq 1.5$ in	design and construct
2 in $< \Delta H \leq 4$ in	1.5 in $< \Delta H_{100} \leq 3$ in	ensure structure can tolerate settlement
$\Delta H > 4$ in	$\Delta H_{100} > 3$ in	obtain approval prior to proceeding with design and construction[1]

[1]Approval of the Soils Design Section required.

Internal Stability Evaluation

The wall designer/vendor is responsible for the Internal Stability, which is the process of analyzing safety against structural failure. Typically, two areas where the rupture and pullout potential are assessed: 1) at the maximum stress zone in the region between the active and resistant zones; and 2) the wall face connection.

Reinforcement Pullout

Reinforcement pullout failure occurs when tensile forces in the reinforcements become larger than the pullout resistance (the force required to pull the reinforcement out of the soil mass).

Reinforcement Strength

Reinforcement failure occurs when the tensile forces in the reinforcement cause excess elongation or rupture, which would lead to large movements and possible collapse of the structure. Strength of reinforcement at every layer must be checked within the wall at the boundary between the active and resistant zones and at the connection between the wall and reinforcement connection.

References

AASHTO, 2012. LRFD Bridge Design Specifications.

Chronology of Changes to Design Manual Section:

200F-003 MSE Walls

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