



3-8 MECHANICALLY STABILIZED EMBANKMENTS

Introduction

This design aid applies to Mechanically Stabilized Embankments (MSE) and related special designs using engineered backfill layered with soil reinforcement. The typical design provided on the attachments is used with Section 13 with the Bridge Standard Detail Sheets (XS Sheets). This design is based on AASHTO Load and Resistance Factor Design (LRFD) *Bridge Design Specifications* (BDS) and the California Amendments to the AASHTO LRFD BDS.

General

Dimensioning

Design height (H) is the maximum height of a given section of an MSE, including proper embedment, plus individual project-specific requirements. Proper embedment is at least $0.1H$, not less than 2 feet. Possible project-specific requirements include scour depth when located along active waterways, additional depth for improved bearing resistance or planned future excavations, and so forth.

Length of soil reinforcement, L , is measured and laid out from the back of the facing at the front of the MSE to the retained soil behind the MSE. All reinforcement layers have uniform length in a given section of an MSE.

Base Width (BW) is defined as the bottom width of the MSE system. It is composed of the thickness of the facing, plus the length of the soil reinforcement L , and at least 1 ft extra engineered backfill to separate steel reinforcement from the retained soil. Minimum BW is $0.7H$, not less than 8 feet. However, most MSE will have a larger BW according to actual loading conditions.

Horizontal berm width (b) is provided in front of an MSE founded on slopes. Minimum b is $0.1H$, not less than 4 feet. Consider increasing b to provide access for future maintenance activities, or to act as a buffer to minor erosion. This berm may need concrete or rock slope protection from significant erosion that could undermine the MSE.



Compaction clearance (*CC*) must be provided on all sides of an obstruction, such as a culvert, pile, utility, etc. located within in the reinforced soil zone of the MSE. Minimum *CC* should be 4 feet where hand-operated compaction equipment is expected to be used and 8 feet where wheel-mounted compaction equipment is to be used. Do not design the MSE with areas of backfill too small to access during construction for proper compaction.

Traffic Barriers

For MSE located adjacent to the traveled way, a traffic barrier is typically placed in front. For MSE with battered or sloped facings, use any free-standing standard barrier adjacent to but not in contact with the facing elements. For MSE with vertical facing, a concrete barrier type 60D (MOD) may be placed against the facing elements as shown on the XS Sheet in Section 13. The modified barrier design has additional steel at the back of the barrier to distribute the collision load across the facing joints and reduce impact damage to individual facing elements.

On top of an MSE, standard concrete barriers and metal beam guard rail need no special design when placed with at least 3 feet clearance between the coping on top of the facing and the barrier or rail. Standard concrete barriers within 3 feet of the coping must be supported by a concrete moment slab such as shown on the XS Sheet in Section 12. The slab must stabilize the barrier under impact loading, since MSE facing elements typically cannot support lateral load or moments imparted by the barrier. Standard metal beam guard rail is not applicable to the slab in this case.

Concrete barriers and support slabs must be continuous for the full length of the MSE with no expansion joints in barrier or slab. Weakened plane joints are acceptable.

Drainage

Moisture can be detrimental to the long-term performance of the MSE. Grade all finished surfaces around and above the MSE to drain away from it. Surface drainage ditches should be lined and sized appropriately.

Avoid placing drainage inlets (DIs) and cross culvert pipes within the MSE. MSE are designed with a service life of 75 years, but culvert pipe and DI connections require maintenance and may need replacement in less time. A significant amount of moisture can be introduced to the reinforced backfill by a minor leak not ordinarily considered in need of maintenance. Special pipe connections may be required to prevent separation of a culvert placed through or under the MSE where differential settlement is anticipated in the foundation materials.

Place an underdrain low in the reinforced zone to remove ground water from the reinforced backfill. The typical underdrain is an 8 inch corrugated perforated plastic pipe (PPP) in permeable material wrapped in filter fabric. When little ground water flow or foundation settlement is



anticipated, a smooth-walled, perforated, rigid plastic pipe, with a minimum diameter of 4 inches may be used. Other configurations, such as a chimney drain or drainage blanket, can be used to intercept more significant ground water flows, such as in cut areas or side-hill fills.

Place underdrain outlets as necessary to drain, or at least every 200 feet along the length of the underdrain. Place separate outlets for each direction of flow at sags in the underdrain profile. The outlets may be installed to drain through the facing, but placement under the leveling pad is preferred. Show the outlet locations on the MSE plans for future maintenance.

Place an impervious membrane on top of an MSE to intercept any surface flows that could contain deicing chemicals or locally occurring salts, alkalis or brine. The membrane should be installed to slope away from the facing and into a dedicated drainage system with outlets directed away from the reinforced zone. Typically the membrane should be at least 30 mils thick and have all seams welded to prevent leakage.

Design the MSE adjacent to active flowing watercourses for differential hydrostatic pressure. Apply a horizontal load at the high-water level equal to a minimum of three feet of water. Use effective unit weights for both the internal and external stability calculations. Use a rapidly draining backfill where tide or river fluctuations are expected to produce rapid drawdown conditions resulting in greater than 3 feet in differential pressure. Use soil parameters appropriate to the backfill selected in this case.

Backfill Soil

High-quality non-aggressive engineered backfill is required for the reinforcement design provided in the attached tables. Backfill materials in compliance with the Standard Specifications will meet or exceed the soil properties assumed in this design. Do not use clay, recycled AC or PCC grindings, organics, or other materials out of compliance with the Standard Specifications for the reinforced zone.

Do not place an MSE in highly aggressive environments such as marine, brackish or stagnant water. Design details to reduce contamination of the reinforced zone of the MSE placed in moderately aggressive environments. Chlorides and sulfates mobilized by rainwater, groundwater, leaking drainage facilities, and highway spills moving out of the native materials behind, adjacent, or under the reinforced zone can lead to premature degradation of the concrete, geosynthetic, and galvanized steel utilized in the MSE.

If the backfill material selected for use is out of compliance with the Standard Specifications, special design the MSE using actual backfill parameters as determined by laboratory testing.

Provide for long-term monitoring of any experimental or highly unusual MSE designs.



Soil Reinforcement

Design most of the soil reinforcement in any section of the MSE to lay level and flat along its length without bends or kinks at obstructions. A bend in the reinforcement can straighten out under the tension from design service loads, which can lead to distortion in the MSE facing over time.

For the MSE supporting a roadway on top, the depth of the roadway structural section and cross slope must be considered when determining soil reinforcement placement details on the plans. The top layer of reinforcement may be sloped downward from the horizontal at the facing connection 5 to 15 %. The next lower level or two may also need to be sloped downward a portion of this amount as needed to maintain at least 6 inches of soil separation between reinforcement levels. Do not design reinforcement to lie on a slope rising above its connection to the facing.

An MSE is constructed in horizontal layers from the bottom up. Maintain horizontal layers of reinforcement when determining the steps in the bottom of the MSE needed to accommodate a sloped foundation along the lay out line (LOL). However, the top most layer of reinforcement is not laid horizontally when the coping has a profile grade. Attach the top soil reinforcement layer to the top panels parallel to the coping profile. Maintain the coping profile for the top level of reinforcement, the entire length of the MSE. This will then place all the top reinforcement at a uniform depth below the finished grade. Eliminate soil reinforcement from lower levels laid on the horizontal where conflicts arise with the top level profile. Maintain at least 6 inches of vertical separation between the facing connections to the soil reinforcement.

Placing soil reinforcement on the plans closer than shown on the attachment typically reduces service loads and still yields a conservative design. Increasing the spacing either horizontally or vertically tends to increase the load in the reinforcement and may negatively impact its design. Redesign the soil reinforcement for modified layouts that increase the spacing.

Facing

An MSE utilizes standardized precast concrete facing panels that are 5 feet square and 6 inches thick, with an additional 2 inches allowed for optional architectural treatment. The panels are placed in a vertical running bond layout, on a concrete leveling pad at least 6 inches deep and 1 foot wide minimum. The concrete leveling pad at the base of the facing panels is a construction aid for panel erection. It is not a footing and does not contain reinforcing steel. It must crack as needed to prevent the more important facing panels from cracking and spalling during compaction efforts or foundation settlement.



The Bridge Standard Detail Sheets (XS Sheets) available in Section 13 are for 5 foot square panels and half panels. Design project-specific details for:

- Top panels following a profile grade
- Corner panels for acute angle points in the LOL
- Full-height end panels where desired
- Single panels with utility openings up to 30 inches in diameter
- Double panels for larger utilities or obstructions such as standard DIs
- Special Design connections and reinforcement layout if climbing vines are to be planted on the MSE. Note: Attached layout tables may not apply under these additional loads.

The flexible jointed MSE facing accommodates a number of other standard facilities. A standard headwall for a culvert crossing can be treated as a large step in the MSE leveling pad. A Type 1 wall can replace one section of an MSE to accommodate a large sign pedestal or buried utility, and so forth. Utilizing the standardized MSE design wherever possible facilitates the use of pre-approved proprietary systems during construction.

Use expansion joint detailing to connect MSE facing to other concrete walls and abutments. The MSE facing is jointed and free to settle in columns but slip joints may be designed to accommodate large amounts of localized differential settlement. Coping and leveling pads should also be jointed in line with slip joints and designed appropriately for the anticipated displacement.

Mechanically Stabilized Embankment Design

The design tables that follow were developed for the two loading cases shown in Attachment 1. They do not apply to geometrically complex MSE such as tiered or stacked MSE. Nor do they accommodate external loading such as large signs, piers, structure loads, etc. Do not use these tables for MSE subject to hydrostatic pressures.

The tables may be applied to MSE oriented back-to-back with overlapping soil reinforcement provided their facings are separated a distance greater than 1.1 times the height of the taller MSE. Do not connect the reinforcement to both of the facings as this drastically changes the loading assumed in these tables. Separate the soil reinforcement in the overlapping zone by at least 4 inches of soil. Consider dropping the leveling pad on one side by as much as one-half the spacing between levels of reinforcement for improved constructability.

Loading

The tables provide design information for MSE with a vertical facing and uniform soil reinforcement lengths for two different load cases (not to be confused with the load combinations defined in AASHTO LRFD BDS). See Attachment 1 for the load case diagrams described here.



Load Case 1

The backfill in this case is horizontal with a distributed traffic surcharge. A standard concrete barrier is included within 3 feet of the coping on a concrete slab. Soundwall weight is not included. Piles designed to stabilize the soundwall under wind and seismic loading are assumed to distribute the weight down through the layers of the MSE. An additional 1.6 feet of soil weight is added on top of the MSE to accommodate the barrier slab and typical roadway structural sections. The Mononobe-Okabe method was utilized for the Extreme Event Limit state analyses. The resulting reinforcement length, L , is equal to or greater than $0.7H$ minimum (not less than 8 feet) for adequate sliding, eccentricity and internal stability.

Load Case 2

The backfill in this case is sloped up from the facing 2 horizontal to 1 vertical. There are no barrier loads, soundwalls, or traffic surcharges included. A minor concrete gutter, safety railing, and coping on top of the facing are allowed. The backslope height has been limited to $3H$, not greater than 115 feet from the base of the MSE. The trial wedge method was utilized for the Extreme Event limit state analyses. The resulting reinforcement length, L , is equal to H (not less than 8 feet) for adequate sliding, eccentricity and internal stability.

The same panel details and facing layout are utilized for both load cases.

Only galvanized steel soil reinforcement is used throughout the MSE. It is laid horizontally from the bottom up, at the horizontal and vertical mat spacing shown on the table. The mat spacing on these tables may be reduced, but not increased. The configuration of the soil reinforcement mats is also shown on the table. Altering the wire size or spacing within the mats may negatively impact the design. Redesign the MSE and the soil reinforcement if modified mat configurations are required.

Passive resistance in front of the MSE is neglected to accommodate future maintenance activities. Stabilizing weight from the facing elements is ignored. The facing elements must be stabilized by mechanical attachment to the soil reinforcement.

Minor movement or distortion in the MSE is acceptable under seismic loading. Collapse is not. Thus typical practice is to apply at least one-third of the site maximum acceleration. The portion of inertia defined in AASHTO LRFD BDS has been utilized, with kh equal to 0.2, applied as defined by the California Amendments.

Bearing capacity, foundation settlement, and global or overall stability must be checked for actual project conditions. Only the sliding, the eccentricity and the internal modes of failure relative to the design heights shown have been checked as adequate under the Service I, Strength Ia, and Ib, and Extreme Event I Limit states in AASHTO BDS, Section 3 as modified by Section 11 and the California Amendments.