# Corrosion of Soil Reinforcements

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# Module 1: Introduction

## Learning Objectives

By the end of this section, you will be able to:

- **Identify** the dual roles of electrochemical techniques and retrieval protocols in Transportation Asset Management (TAM).
- **Evaluate** the impact of material selection and soil-reinforcement interaction on the durability of Mechanically Stabilized Earth (MSE) structures.
- **Select** appropriate monitoring methodologies based on reinforcement type, whether metallic or geosynthetic.

*Executive Summary:* This manual serves as the primary Federal Highway Administration (FHWA) reference for the long-term performance and durability of soil reinforcements. It provides standardized criteria for evaluating corrosion in steel reinforcements and degradation in polymeric reinforcements using mature, field-proven electrochemical and destructive testing technologies.

## Design Objectives and Fundamentals

The construction of **Mechanically Stabilized Earth (MSE)** systems has achieved widespread acceptance for retaining walls and steepened slopes. The primary engineering challenge is ensuring these structures perform reliably over their full **design life**.

# The Composite Material Concept

The design of MSE structures relies on creating a composite structural material by combining select soil with reinforcements.

- **Judicious placement** of reinforcements restrains soil deformation parallel to the reinforcement.
- **Performance** depends heavily on proper material selection, construction precision, and ongoing maintenance.

## Common Reinforcement Types

- **Galvanized Steel:** Historically used in 80% to 90% of transportation projects, typically in strip or grid configurations.
- **Polymeric/Geosynthetic Reinforcements:** Introduced in the 1970s and 80s, these now represent the majority of reinforcements used in **Reinforced Soil Slopes (RSS)**.

# Durability and Monitoring Aim

A major design concern is reinforcement durability within the soil/water environment. This manual provides a dual-track approach to monitoring:

- **Metallic Reinforcements:** Utilization of **non-destructive** remote electrochemical equipment to determine in-situ corrosion rates and section loss.
- **Polymeric Reinforcements:** Implementation of **retrieval protocols** and destructive testing to measure changes in polymer structure and loss of tensile strength.

💡 **Design Tip:** Consider the performance of MSE structures within the broader context of **Transportation Asset Management (TAM)**. Mature monitoring technologies are now essential tools for documenting performance and optimizing resource allocation.

## Scope of Work

The scope of this technical manual covers the following critical areas:

- **Mechanisms of Deterioration:** Detailed descriptions of corrosion in metallic systems and degradation in geosynthetic reinforcements.
- **In-Situ Measurement:** Techniques and instrumentation for measuring real-world corrosion rates in steel reinforcements.
- **Laboratory Analysis:** Review of electrochemical test methods for reinforced fill materials and their relationship to durability predictions.
- **Protective Coatings:** Criteria for determining the survivability of **fusion bonded epoxy coatings**.
- **Geosynthetic Evaluation:** Identification of degradation mechanisms and monitoring methods specific to in-ground polymeric regimes.

## Document Organization

The manual is structured to provide a comprehensive progression from fundamentals to field application:

- **Module 2:** Fundamentals of metallic corrosion in soil and identification of corrosive environments.
- **Module 3:** Field monitoring methods for metallic reinforcements in new and existing construction.
- **Module 4:** Fundamentals of polymer degradation and identifying soil regimes that accelerate aging.
- **Module 5:** Implementation of monitoring and retrieval methods for geosynthetic reinforcements.

## Project NCHRP 24-28 and LRFD Integration

The **NCHRP 24-28** study focuses on incorporating improved predictive models into a **Load and Resistance Factor Design (LRFD)** approach for MSE structures.

## Project Goals and Deliverables

1. **Performance Database:** Documenting attributes and observed metal loss from in-service reinforcements.

2. **Updated Models:** Refined metal loss models accounting for various site conditions and confidence levels.

3. **Resistance Factors:** Recommended factors for LRFD designs based on estimated service life metal loss.

4. **Standardized Practice:** Specific guidance on sampling, testing, and design procedures related to corrosion.

⚠️ **Safety Constraint:** The current AASHTO model for metal loss is strictly applicable only to galvanized reinforcements and reinforced fill that meet specific **electrochemical requirements**.

## Impact of Marginal Fills

Fieldwork for NCHRP 24-28 included data collection on "marginal" quality fills—those with resistivity (r) less than **3000 W-cm**. This data is used to evaluate service life impacts when stringent fill requirements cannot be met.

🧮 **Calculation Note:** Variance in reinforced fill quality, climate, and site conditions significantly impacts the uncertainty of metal loss. Use the data from NCHRP 24-28 to assess the reliability of your service-life estimates.

*Checkpoint Quiz*

1. **Which material combination constitutes the majority of current applications for MSE retaining walls on transportation projects?**
   a) Plain black steel strips with cast-in-place facings.
   b) Galvanized steel strips or grids with precast concrete facings.
   c) Geosynthetic grids with wrapped-face soil slopes.
   d) Epoxy-coated bars with timber facings.

**Answer:** (b). Galvanized steel in strip or grid configuration represents approximately 80 to 90 percent of applications to date.

2. **How is the monitoring of section loss in metallic soil reinforcements primarily achieved?**
   a) Visual inspection of the wall facing for rust stains.
   b) Periodic excavation and physical measurement of every reinforcement layer.
   c) Remote electrochemical measurements and in-situ corrosion rate determination.
   d) Constant monitoring of the structure's total weight.

**Answer:** (c). Non-destructive field evaluation systems use remote electrochemical equipment to determine in-situ rates and infer section loss.

3. **Under the NCHRP 24-28 project, what is the significance of studying "marginal" quality fills (r < 3000 W-cm)?**
   a) To prove that these fills should never be used under any circumstances.
   b) To develop adjustments for metal loss models when fills do not meet standard electrochemical requirements.
   c) To replace galvanized steel with polymeric reinforcements in all future projects.
   d) To eliminate the need for LRFD resistance factors in MSE design.

**Answer:** (b). These data are used to evaluate parameters and adjustments needed to estimate the impacts of marginal fills on service life.

# Module 2: Corrosion Of Metallic Reinforcements

## Learning Objectives

By the end of this section, you will be able to:

- **Identify** the electrochemical fundamentals and environmental factors that drive the corrosion of buried metallic reinforcements.
- **Evaluate** soil corrosivity using key index parameters including resistivity, pH, and soluble salt content.
- **Calculate** sacrificial steel thickness requirements based on AASHTO uniform loss models for a specified design life.

*Executive Summary:* The engineering approach to managing corrosion in MSE structures involves a two-pronged strategy: (1) specifying select backfill with controlled electrochemical properties to minimize activity, and (2) adding a sacrificial thickness to the structural steel to account for projected metal loss over the 75-to-100-year service life.

## Fundamentals of Corrosion of Metals in Soil

Corrosion is the electrochemical deterioration of metal as it reverts to its native state of oxides and salts. In MSE structures, accelerated corrosion can lead to catastrophic failure along the plane of maximum tensile stress, typically located **0 to 0.3H** from the wall face.

### The Electrochemical Process

Corrosion occurs due to a potential difference between two points on a metal surface in the presence of an **electrolyte** (soil moisture).

- **Anodic Area:** Where current leaves the metal and enters the soil; this is where metal loss occurs.
- **Cathodic Area:** Where current returns to the metal; this area is generally protected.
- **Electrolyte:** Soil containing moisture and soluble salts that facilitates ion transport.

### Corrosion Types

- **General Corrosion:** Uniform thinning over a large surface area.
- **Pitting Corrosion:** Localized, deep indentations that can compromise structural integrity more rapidly than uniform loss.