CHAPTER 1 — INTRODUCTION

1.1 BACKGROUND

Federal Lands Highway (FLH), a program of the Federal Highway Administration (FHWA), is responsible for design and construction of roadways in rugged, mountainous terrain. Where the terrain is steep, retaining walls are frequently required in order to accommodate widening of existing roads, or construction of new roadways. In the last 20 years, use of various types of mechanically stabilized earth (MSE) retaining walls has increased on FLH projects, proving to be reliable, constructible, and cost effective.

MSE walls are typically used to allow construction of a new road or widening of an existing narrow road by constructing the MSE wall on the outboard or "fill side" of the roadway. MSE walls behave as a flexible coherent block able to sustain significant loading and deformation due to the interaction between the backfill material and the reinforcing elements. Since MSE walls are essentially used to strengthen fills, this approach is generally ideal for such fill-side retaining walls. However, in steep terrain, a flat bench must be excavated on which the MSE wall is constructed. Existing state-of-practice design methods for MSE walls in the public sector suggests a minimum bench width equivalent to seventy percent of the design height (i.e., $0.7H$).[1,2] Additionally, required toe embedment depths for MSE walls are proportional to the steepness of the slope below the wall toe. In some cases, the excavation requirements for construction of an MSE wall become substantial and unshored excavation for the MSE wall is not practical, particularly if traffic must be maintained during construction of the MSE wall.

Shoring walls, often soil nail walls, have been employed to stabilize the backslope (or back-cut) for construction of the MSE wall, with the MSE wall being designed and constructed in front of the shoring wall. When a composite MSE and shoring wall system is proposed for use on a project, the MSE wall component of the system should consider the long-term retaining benefits provided by the shoring wall, including reduction of lateral loads on the MSE wall mass and significant contributions to global stability. Therefore, this investigation is based on the hypothesis that using current MSE wall design methods are conservative for Shored Mechanically Stabilized Earth (SMSE) wall systems. Where data are not present to show otherwise, the design methodology presented in this report generally refers back to current design practices.[1,2]

1.2 OBJECTIVE

The purpose of this report is to present a design procedure for SMSE wall systems that rationally considers the stabilizing effect of the shoring wall on the long-term stability of the MSE wall mass. This report has been developed to serve as an FLH reference for projects involving the use of SMSE wall systems. State Departments of Transportation (DOT) and others may also find the results and recommendations useful for the design of more cost effective wall systems.

Current design practice for MSE walls used by FHWA is Elias et al.[2] This report does not replace that work, but instead expands that work for projects where SMSE wall systems are

viable and may provide cost advantages. The design methodology and recommendations presented in this report were developed based on a literature review (presented in appendix A), results of laboratory-scale centrifuge modeling (presented in appendix B), field-scale testing (presented in appendix C), and numerical modeling (presented in appendix D).

This report is not written for design of MSE veneers on shoring walls. Such walls are fundamentally different from SMSE walls in that they are typically "cut side" veneers. The MSE veneer is applied typically to provide an aesthetic improvement to the face of the shoring wall, and does not support vehicle traffic or contribute significantly to global stability of the roadway.

1.2.1 Scope

This report addresses the following items:

- Considerations to evaluate regarding when to use an SMSE wall system.
- Field investigation for an SMSE wall system.
- Failure mechanisms of an SMSE wall system.
- Internal stability design of the MSE wall component of an SMSE wall system.
- External stability design of the MSE wall component of an SMSE wall system.
- Global stability of the SMSE wall system.
- SMSE wall system design details.
- Shoring wall component, specifically soil nail wall, design details and considerations.
- Items to include in a Supplemental Contract Requirement (SCR).
- A discussion on procurement and constructability issues related to SMSE wall systems.

The details of the pre-decision evaluation studies and the decision to use an SMSE wall system are presented in chapter 2. Chapter 3 presents results of the literature review, centrifuge modeling, field-scale testing, and numerical modeling; summarizes the design basis for SMSE wall systems; and presents design considerations for SMSE wall systems. Chapter 4 provides a discussion regarding site investigations for SMSE wall systems. The design of the MSE wall component of an SMSE wall system is presented in chapter 5. Design considerations for the shoring wall component, specifically a soil nail wall, are discussed in chapter 6. A design example is presented in chapter 7. Issues regarding procurement and constructability of SMSE wall systems are presented in chapter 8. Chapter 9 provides conclusions and recommendations.

1.2.2 Source Documents

Where design of the MSE wall component of an SMSE wall system is similar to that of a traditional MSE wall, design methodology was extracted from Elias et al., *Mechanically Stabilized Earth Walls and Reinforced Soil Slopes, Design and Construction Guidelines* and the American Association of State Highway and Transportation Officials (AASHTO) *Standard Specifications for Highway Bridges.*[1,2] Reference to other documents used for development of this report are provided in the literature review in appendix A.

1.2.3 Terminology

Certain terms will be used throughout this report, defined as follows:

- Aspect ratio is the term given to the ratio of the length (L) of reinforcing elements to the height (H) of the wall for an MSE wall system.

- Facing is a generic term given to the face of a retaining wall, used to prevent the backfill soil from escaping out from between the rows of reinforcement.

- Geosynthetic is a term for a planar product manufactured from polymeric material used with soil, rock, earth, or other geotechnical engineering related material as an integral part of a man-made project, structure or system.

- Mechanically Stabilized Earth (MSE) wall is a generic term used when multiple layers of tensile inclusions act as reinforcement in soils placed as fill for construction of a wall having a vertical or near-vertical face.

- Reinforcing elements (or reinforcements) is a generic term that encompasses all man-made elements incorporated in soil (as in an MSE wall) to improve its behavior (i.e., geotextile sheets, geogrids, steel strips, steel grids, etc.).

- Reinforced fill is the fill material in which the MSE wall reinforcements are placed.

- Retained backfill is the fill material behind the reinforced backfill zone on a conventional MSE wall system.

- Shoring system is a generic term for a retaining wall used to provide vertical or near-vertical support of an excavation.

A glossary presented at the end of this report defines other terminology used throughout this report. A generic cross section of an SMSE wall system illustrating several of the above terms is shown in figure 1.

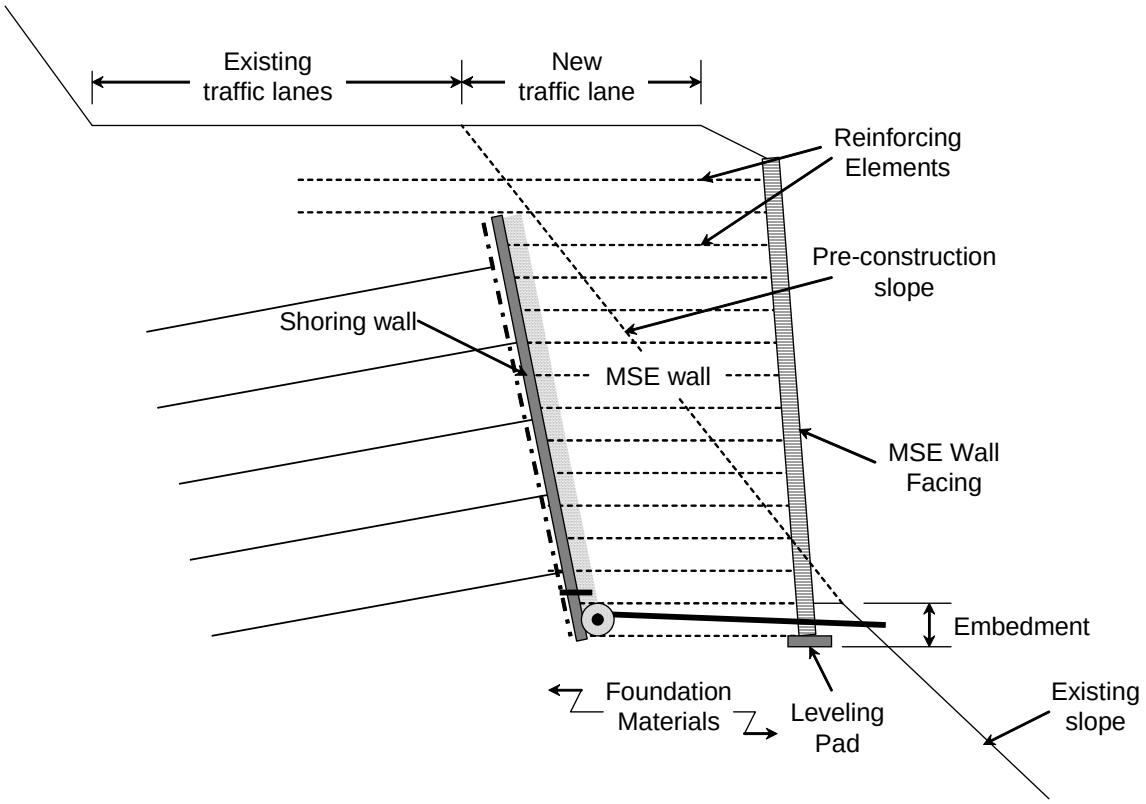

Figure 1. Diagram. Generic cross section of an SMSE wall system.

1.3 PRELIMINARY RESULTS

Based on the results of centrifuge modeling (appendix B) and field-scale testing (appendix C) of an SMSE wall system employing short reinforcements, reduction of the reinforcement length to as little as 25 percent of the wall height (0.25*H*) provide sufficient wall stability, even under a considerably high degree of surcharge loading. Using the results of this research, a minimum reinforcement length equivalent to 30 percent of the wall height (0.3*H*) as measured from the top of the leveling pad is recommended for design of the MSE wall component of an SMSE wall system. Reinforcement length is recommended to be not less than 1.5 m for SMSE walls, which is less than the 2.4 m minimum reinforcement length set forth in AASHTO and Elias et al. for traditional MSE walls.[1,2]