



## 5-19 EARTH RETAINING SYSTEMS COMMUNICATION

### Overview

This memo presents the communications protocol between the Structure Designer and Geotechnical Designer during the design of the various types of earth retaining systems (ERS) included in Topic 210 of the Highway Design Manual (HDM). The definitions, parameters, design methods, and processes herein follow *AASHTO Load and Resistance Factor Design, Bridge Design Specifications with the California Amendments* (AASHTO LRFD). This memo includes lists and tables containing the information exchanged between the Structure Designer and Geotechnical Designer. The information identified in this memo is adequate for most ERS designs. However, additional information may be identified to address special ERS cases.

### Types and Application

Earth retaining systems are used to retain earth and maintain a difference in the elevation of the ground surface. Earth retaining systems can have various applications in highway design and are commonly used in new or widened highways, grade separations, tunnel portals, cofferdams, and slope stabilization. The ERS described here do not support superstructure loads. Bridge abutments are not addressed in this memo.

Earth retaining systems can be classified by load support (externally or internally stabilized systems), or by construction method (cut or fill systems). The following commonly used ERS are classified according to AASHTO LRFD with additional information from HDM 210.

- **Gravity walls** (i.e., conventional retaining walls) derive their capacity to resist lateral loads through the dead weight of the wall itself. These walls include massive concrete gravity walls and rock gravity walls. These types of ERS can be utilized in both cut and fill wall applications. Excessive differential settlement can cause cracking, excessive bending, or shear stress in concrete gravity walls. Due to their rigidity, these walls are rarely used in California's seismic zones.
- **Semi-gravity walls** are similar to gravity walls, except they rely on their structural components to mobilize the dead weight of a portion of the backfill to derive their capacity to resist lateral loads. These walls include Retaining Walls (Types 1, 1A, 5, 6 and 7) published in the Standard Plans and the Standard Details (XS Sheets). These types of ERS can be effective for both cut and fill wall applications. Excessive differential settlement can cause cracking, bending, or shear stress in these walls.



- **Non-gravity cantilevered systems** rely on structural components of the vertical elements partially embedded in foundation material to mobilize resistance against lateral loads. These ERS include sheet pile walls, soldier pile walls with and without lagging, tangent pile walls, and secant pile walls. Many may also include ground anchors. These systems are most practical in cut sections, but can also be used in fill locations.
- **Anchored systems** derive their capacity to resist lateral loads by their structural components being connected to anchors behind the structural face. The anchors may be drilled and grouted ground anchors (formerly known as tiebacks), passive concrete anchors (formerly known as deadmen), passive pile anchors, or pile group anchors. The anchors can be connected directly to wall structural components or to other structural components such as footings, grade beams, piling or walers across soldier piles. Soil nail walls are a special type of anchored system without the pre-stressed design load typically locked into ground anchors during construction. Soil nails are sometimes referred to as passive systems. However, the use of the term 'rock bolt' does not apply in this class of ERS, since they are typically designed for slope improvement without incorporating a wall, and do not use the loading common to ground anchor and soil nail design methods. This class of ERS is most applicable for cut sections.
- **Mechanically Stabilized Embankments (MSE)** derive their capacity through the dead weight of the reinforced soil mass stabilized by interface shear and passive resistance between the engineered backfill soil and layers of soil reinforcement. The soil reinforcement can be metallic (strip, bar grid, or wire mesh) or polymer (strip, grid, or sheet). Facings can be precast concrete panels, modular block, wire mesh, and open faced or plantable units. Additionally, many of the prefabricated modular systems below can also be used to face MSE. MSE systems may be considered where substantial total settlements are anticipated. MSE are used in fill sections.
- **Prefabricated modular walls** are similar to gravity walls, except they derive their capacity through a combination of the dead weight of the infill soil contained by the system elements and some limited amount of structural resistance. They are typically much more flexible than gravity systems and most can tolerate large total settlement. However, excessive differential settlement can cause cracking, excessive bending, or shear stress in the system elements that could cause a loss of the infill soil and lead to system failure. These systems are typically composed of interlocking prefabricated units, including concrete cribs, metal bins, gabion baskets, open blocks or large solid blocks. When they are used to face an MSE they are no longer included in this classification. This class of ERS is most applicable to fill sections.

More information on ERS can be found in HDM, Topic 210.



## Design Requirements

The roles and responsibilities of the Structure and Geotechnical Designers during the multiple communications involved in designing ERS following AASHTO LRFD are as follows:

- Standard Plan ERS – The Geotechnical Designer must determine if the geotechnical parameters at the ERS location meet or exceed the geotechnical parameters used for the ERS design. There is no need to analyze and provide recommended design lateral earth pressures or passive resistances for Standard Plan ERS.
- Special Design ERS – The Geotechnical Designer is responsible for the following:
  - The stratigraphy, material parameters, and the recommended lateral earth pressure distribution to apply
  - The Overall stability of the ERS on-site, under the Service 1 and Extreme 1 Limit State Analyses
  - The bearing resistance of the on-site foundation materials
  - The anticipated magnitude of the total and differential settlement
  - Log of Test Borings and laboratory test results
  - Any construction considerations on the project site

The Structure Designer is responsible for the layout and detailing that may affect the final height, depth, width or overall size of all special design ERS. The Structure Designer is therefore responsible for the following:

- The Service 1, Strength 1a and 1b, and the Extreme 1 Limit State analyses
- The Extreme 2 Limit State analysis involving vehicular collision loads, where applicable
- The bearing demand of the system does not exceed the bearing resistance provided by the Geotechnical Designer
- The calculated pile loads including lateral loads
- The design tip elevation for the lateral loads
- Informing the Geotechnical Designer of dimensional or loading changes that can affect the geotechnical design recommendations



Permissible settlement tolerances under Service Loads shall be developed based on the function, service life, and consequences of unacceptable settlement to the ERS and any potentially affected nearby structures. There are two aspects of deformation to be considered:

1. Deformation of the retained zone due to lateral deformation typical of the ERS technology chosen.
2. Vertical deformation caused by settlement of the foundation materials due to a change of ground surface profile.

Allowable lateral deflection at top of wall shall be selected based on the function, service life, and consequences of unacceptable deflection to the wall and nearby structures.

When unsuitable soil layers (very soft, liquefiable, above scour elevation, etc.) are present, the nominal driving resistance during construction of a pile is not equal to the nominal resistance needed to support the factored loads during design. Although they do not contribute to the design resistance, the unsuitable layers will be penetrated by the driven pile. The nominal driving resistance reported must then also include the driving resistance from the unsuitable layers. The locations and elevations of unsuitable soil layers must be reported.

## Communication

Communication between the Structure Designer and Geotechnical Designer needs to occur as frequently as necessary to ensure efficient and timely delivery of all ERS geotechnical components. The ERS design process is an iterative process requiring effective communication. Design recommendations are dependent upon the factored load demands of the system and the system configuration, as well as the geotechnical environment in which it will function.

Upon request from the Structure Designer, the Geotechnical Designer will provide a Structure Preliminary Geotechnical Report (SPGR), Preliminary Foundation Report (PFR), and Foundation Report (FR) for ERS projects. The Structure Designer will request each of these reports in a formal memorandum sent from the Structure Design Branch Chief to the Geotechnical Design Office Chief. The Geotechnical Designer will transmit each report to the Structure Design Branch Chief who made the request.

The following Overview summarizes the WBS elements, tasks, and associated responsibilities of the Structure Designer and Geotechnical Designer through the development of the Structure Plans, Specifications, and Estimate (SPS&E) package to the completion of the project.



**Overview of WBS Elements, Tasks, and Responsibilities**

WBS Elements	Tasks	Structure Designer	Geotechnical Designer	
Advance Planning Study (APS) (WBS 150, 160)	1 Advance Planning Study	Request Structure Preliminary Geotechnical Report (SPGR). (Attachment 1 required)	Acknowledge receipt of request and provide name of Geotechnical Designer assigned.	
			Provide SPGR.	
Draft Structure PS&E (WBS 240)	2 Preliminary Foundation Report	Request Preliminary Foundation Report (PFR). (Attachment 2 required)	Acknowledge receipt of request and provide name of Geotechnical Designer assigned.	
			Provide PFR .	
	4 Foundation Report	3 Draft Structure General Plan	Discuss feasible ERS types prior to Type Selection with Geotechnical Designer. Invite Geotechnical Designer to the Type Selection Meeting.	Discuss appropriate ERS types and recommended foundation types. Attend the Type Selection Meeting.
			Request Foundation Report (FR) Update preliminary design information as necessary after Type Selection. (Attachment 3 required).	Acknowledge receipt of request and provide name of Geotechnical Designer assigned. Provide Draft Foundation Report with preliminary information for design. (see Attachment 4 for format)
			Review Draft Foundation Report and provide comments, if any. Verify or update design data including design loads (Attachment 3 required). (Note: Revisions of Draft FR and updates of design data may occur more than once)	Provide revised Draft Foundation Report including LOTBs (see Attachment 4 for format). (Note: Revisions to the Draft Foundation Report may occur more than once)
	Request Constructability Review of draft Structure Plans by Geotechnical Designer.	Review Draft Structure Plans for constructability and consistency with Foundation Report and send comments to Structure Designer. Provide signed Foundatuion Report.		
Final SPS&E Package (WBS 250)	5 Project Review	Send Draft SPS&E package and request Foundation Review.	Review Draft SPS&E package and issue Foundation Review concurrence.	
Awarded & Approved Const. Contract (WBS 265)	6 Advertised Contract	Structure Designer and/or Specification Writer request Geotechnical Designer to respond to bidder inquiries.	Provide bidder inquiry response to Structure Designer and/or Specification Writer.	
Construction Engineering and General Contract (WBS 270, 275)	7 Construction Engineering Work	Structure Designer/Structure Representative request technical support during construction (i.e., VECP review, pile mitigation, foundation testing and CCO support).	Provide technical support to Structure Designer and Structure Representative.	
As-Built Plans (WBS 295)	8 Project Completion	Develop As-Built Plans (with Shop Plans of Proprietary Products) for BIRIS	N/A	



## 1. Advance Planning Study

Early in the advance planning stage (Phase “K” or “0”), the Structure Designer may request an SPGR to develop a planning study. The request is made via a transmittal memo and should include the following information:

- Attachment 1
- Location Map and aerial photos
- Any As-Builts available
- Scope of proposed work
- Description of any site constraints
- Proposed ERS types and locations
- Foundation type and location being considered
- ERS layout
- Cross-sections and elevation view
- Any Hydraulic information or Preliminary Hydraulic Report

The SPGR provided by the Geotechnical Designer should include the following information:

- Feasible ERS types
- Advantages and disadvantages
- Recommended ERS
- Any existing corrosion data
- Any known site conditions

## 2. Preliminary Foundation Report (PFR)

Early in the design stage (Phase “1”) and after bridge site submittal, the Structure Designer will request a PFR to develop a draft structure General Plan. The request is made via a transmittal memo and should include the following information:

- Applicable table(s) from Attachment 2
- Scope of proposed work
- Project Schedule
- PFR due date
- Proposed ERS types and locations
- Location map
- Preliminary layout of ERS (include APS when available)
- Cross-sections and elevation view
- Foundation type and location being considered
- Any hydraulic information or Preliminary Hydraulic Report
- Any Scour data



The PFR provided by Geotechnical Designer should include the following:

- Subsurface conditions including groundwater
- Geologic hazards (e.g. Fault, Fault Style, Magnitude, Distance, and PGA)
- Feasible ERS type(s)
- Recommended ERS type
- Feasible foundation type(s)
- Recommended foundation type
- Constructability
- Corrosion and/or hazardous waste evaluation
- Drainage considerations

### 3. Draft Structure General Plan

The Structure Designer may prepare a Type Selection Report and schedule Type Selection Meeting (not all projects will have more than one feasible ERS type in which case a Type Selection Meeting may not be required if all functional units confirm the ERS type). When scheduling a Type Selection Meeting, the Structure Designer will invite:

- Geotechnical Designer
- District Project Manager
- District Project Engineer
- Structure Construction
- Other functional units involved in the project

It is recommended that the Structure Designer contact the Geotechnical Designer prior to the Type Selection Meeting to discuss the information in the PFR and the Type Selection Report.

### 4. Foundation Report (FR)

After type selection, the Structure Designer will request an FR to develop plans, specifications and estimate (PS&E). The request is made via a transmittal memo and should include the following information:

- Applicable table(s) from Attachment 3
- Scope of proposed work
- FR due date
- Site plans
- Draft general plan
- ERS type(s) being considered
- Preliminary design loads
- Structure plan showing wall location and elevations



- Cross sections and elevation view
- Any utility or roadway drainage facility locations impacting the ERS
- Hydraulic Report

The Geotechnical Designer is to provide a draft FR for review and comment. The Structure Designer will review the draft FR and will provide comments, if any, including verification or submittal of final design loads to the Geotechnical Designer. Depending on the scope of structure work or complexity of the ERS, more than one draft FR may be necessary prior to a signed FR. The signed FR provided by the Geotechnical Designer should include the following:

- Foundation recommendations
- Shallow foundation and/or pile data tables as shown in Attachment 4

The Geotechnical Designer must send a Log of Test Borings (LOTB) to the Structure Designer, immediately following the signed FR.

## 5. Project Review

The Structure Designer will schedule a Constructability Review (CR), and request the Geotechnical Designer to participate in the CR and to review draft SPS&E for conformance with the FR.

Structure Designer will provide the following:

- Draft SPS&E package for review and comments
- Due date for review comments

The Geotechnical Designer will:

- Attend Constructability Review Meeting
- Review and send comments on Draft SPS&E package

The Structure Designer must request a Foundation Review when the Structure P&Q has been completed and the Draft Structure Specifications are available for review. In addition, the Structure Specification Engineer shall be contacted by the Structure Designer for participation and input in the Foundation Review. At the conclusion of the Foundation Review, the Geotechnical Designer provides a signed Foundation Review Form to the Structure Designer, which they will sign, make a copy for their records and return one signed copy to the Geotechnical Designer.





## 6. Advertised Contract

The Structure Specification Engineer requests support from both the Structure Designer and the Geotechnical Designer during the contract development process. The Structure Designer and Geotechnical Designer may also help address bidder inquiries pertaining to ERS.

## 7. Construction Engineering Work

Construction staff may request technical support from the Structure Designer and Geotechnical Designer during construction. When requested, the Structure Designer and Geotechnical Designer will provide:

- Technical Support with contract documents and design requirements
- CCO concurrence and other design changes as needed
- Shop drawing review and approval
- Value Engineering Change Proposal (VECP) Review

## 8. Project Completion

The Structure Designer will develop As-Built Plans (with Shop Plans of proprietary systems) for BIRIS.

## Attachments

Foundation data tables of various types are included as attachments to this memo. They are not exhaustive, nor are they complete by themselves, since they cannot contain all information needed for the design of any particular type of ERS. These tables are included to assist in the minimum needed information to exchange during communications at the various stages of design.

1. Attachment 1 contains the Summary of Proposed Earth Retaining Systems. This table contains the minimum information to be sent to the Geotechnical Designer for each proposed ERS on the project, along with the request for the SPGR.



2. Attachment 2 contains the Preliminary Foundation Data Tables. These tables contain the minimum information for each proposed ERS on the project to be sent to the Geotechnical Designer, along with the request for the PFR. Choose the table or tables that apply to the project.
  - Preliminary Foundation Data Table For Special Design ERS
  - Preliminary Foundation Data Table For A Modified Standard Plan On Spread Footing
  - Preliminary Foundation Data Table For A Modified Standard Plan On Piles
3. Attachment 3 contains the Geotechnical Design Data Tables. These tables contain the minimum information to be sent to the Geotechnical Designer, along with the request for the FR. Choose the table or tables that apply to the projects.
  - Geotechnical Design Data Table - Parts 1 and 2 (Note this table is in two parts, and both must be sent together)
  - Geotechnical Design Data Table For A Modified Standard Plan On Plies
4. Attachment 4 contains two sets of tables, a pair for shallow foundations and a pair for piles. Each pair consists of Design Recommendations and the corresponding Data Table for the contract documents. The appropriate set or sets must be included in the final FR.
  - The Shallow Foundation Design Recommendations (For special design use only) shows the format for information provided by the Geotechnical Designer to be included in the FR. (Note this table is in two parts, and both must be sent together)
  - The Shallow Foundation Data Table shows the format for information provided by the Geotechnical Designer to be included in the Contract Plans.
  - The Pile Foundation Design Recommendations shows the format to be included in the FR for standard plan walls on standard plan piles. The design tip elevations for lateral loads are determined by the Structure Designer.
  - The Pile Data Table shows the format to be included in the Contract Plans for Standard plan walls on standard plan piles. The design tip elevation for lateral loads are determined by the Structure Designer.



## References

This document was based on the following guidance materials within the Department:

1. *Bridge Design Aids 3-7, Pile Layouts For Standard Plan Retaining Walls* (2014)
2. *Bridge Design Aids 3-8, Mechanically Stabilized Embankment* (2013)
3. *Bridge Standard Detail Sheets (XS Sheets), Section 12 Earth Retaining Systems* (2014)
4. *Bridge Standard Detail Sheets (XS Sheets), Section 13 Mechanically Stabilized Embankment* (2014)
5. *Bridge Standard Detail Sheets (XS Sheets), Section 14 Retaining Walls with Soundwalls* (2014)
6. *California Amendments to the AASHTO LRFD Bridge Design Specifications – 6th Edition* (2014)
7. *Caltrans Corrosion Guidelines, Version 2.0* (2012)
8. *Highway Design Manual* (2014)
9. *Memo-To-Designers 1-5, Distribution of Plans* (1996)
10. *Memo-To-Designers 1-35, Foundation Recommendations and Reports* (2008)
11. *Memo-To-Designers 2-12, Special Design Earth Retaining Systems Numbering* (2012)
12. *Memo-To-Designers 3-1, Deep Foundations* (2014)
13. *Memo-To-Designers 4-1, Spread Footings* (2014)
14. *Memo-To-Designers 5-5, Design Criteria of Standard Earth Retaining Systems* (2014)
15. *Memo-To-Designers 5-12, Earth Retaining Systems Using Ground Anchors* (2012)
16. *Memo-To-Designers 5-14, Review of Shop Drawings for Ground Anchors* (2012)
17. *Memo-To-Designers 5-20, Foundation Report/Geotechnical Design Report Checklist for Earth Retaining Systems* (2004)



18. *Standard Plans 2010, Crib Walls (C Sheets)*
19. *Standard Plans 2010, Retaining Walls (B Sheets)*
20. *Standard Specifications 2010, Section 46 (Ground Anchors and Soil Nails)*
21. *Standard Specifications 2010, Section 47 (Earth Retaining Systems)*
22. *Standard Specifications 2010 - Section 49 (Piling)*
23. *Workplan Standards Guide, Release 11.0 (2014)*

Additional references –

1. *AASHTO LRFD Bridge Design Specifications*, 6th Edition, American Association of State Highway Transportation Officials, Washington DC, 2012.
2. Report Number FHWA-IF-06-017 GEC No. 7, *Soil Nail Walls*, U.S. Department of Transportation, Federal Highway Administration, 2003.
3. Report Number FHWA-NHI-09-087 *Corrosion/Degradation of Soil Reinforcement*, U.S. Department of Transportation, Federal Highway Administration, 2009.
4. Report Number FHWA-NHI-10-024 GEC No 11 *Design of Mechanically Stabilized Earth Walls and Reinforced Soil Slopes*, Volumes I and II, U.S. Department of Transportation, Federal Highway Administration, 2009.

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