11.29 SEISMIC DESIGN CRITERIA FOR EARTH RETAINING SYSTEMS

11.29.1 Scope

This policy provides seismic design criteria for ordinary earth retaining systems (ERS) built within the State Right of Way.

This policy does not apply to ERS in the following circumstances:

- Site has geotechnical complexities such as excessive amount of soft clay, surface rupture, liquefaction, lateral spreading, and other geotechnical instabilities
- Tunnel portal wall
- Located such that failure would cause substantial economic impact
- Located such that the sponsoring district or local agency has designated serviceability of the ERS as critical

11.29.2 ERS Seismic Design for Safety and Functionality

Safety and functionality of an ordinary ERS is considered to be preserved if movement of the ERS under the Safety Evaluation Earthquake (SEE) defined in Caltrans' Seismic Design Criteria (Caltrans, 2019a) is limited to a mean displacement of 5 inches without loss of overall, external, and internal stability of the ERS.

11.29.3 No Seismic Analysis

In addition to the provisions in Article 11.5.4.2 of AASHTO LRFD Bridge Design Specifications (AASHTO 2017), seismic design shall not be considered mandatory at sites where the site adjusted peak ground acceleration is less than or equal to 0.6*g* for an ordinary retaining wall in the Standard Plans. This provision does not apply when the wall supports another structure that requires specified performance of the wall. If the wall is part of a bigger slope, the overall stability of the slope and the wall must be evaluated.

11.29.4 Design Methods

11.29.4.1 Analysis Methods

Conventional methods include Mononobe-Okabe equation, trial wedge method, and generalized limit equilibrium method for overall, external, and internal stability analyses.

The methods used for displacement analysis are a simplified form of Newmark Sliding Block method, Newmark Sliding Block method and advanced numerical methods (FEM or FDM).

Advanced numerical methods include Finite Element Method (FEM) and Finite Difference Method (FDM) for overall, external, and internal stability analyses. Advanced numerical methods are beyond the scope of this STP.

11.29.4.2 Horizontal Peak Ground Acceleration (*HPGA*)

Horizontal peak ground acceleration (*HPGA)* is the acceleration at zero period extracted from design response spectrum (*HPGA* is the same as *PGA* in the current Caltrans Seismic Design Criteria) at the base of the ERS:

$$k_{h0} = \frac{HPGA}{g}$$

11.29.4.3 Design Methodology

Table 11.24.4.3 summarizes how the loads and the displacement or deformation are obtained using either the conventional methods or the advanced numerical methods for conventional gravity and semi-gravity walls.

Standard design retaining walls are available in Caltrans' Construction Standards as Standard Plans. Based on performance of retaining walls in California during past seismic events, these standards are deemed to satisfy most site conditions encountered in a typical project for an ordinary retaining wall. Thus, a "benchmark" k_h of 0.2 has been assumed. When k_h is taken as $\frac{1}{3}k_{h0}$, and k_{h0} is equal to 0.6, the Standard Plan walls are expected to have a permanent expected mean displacement up to 5 inches. Use of the standards for greater levels of acceleration is permitted so long as the anticipated displacement is calculated and acceptable.

Table 11.29.4.3 Design Methodology

Design Methods	k_h Limits	Combination of Seismic-induced Forces	Expected Mean Displacement/ Movement/ Deformation	Displacement Analysis Method
Conventional methods based on k_h	$k_h \geq \frac{1}{2}k_{h0}$	Largest of: $P_{seis} = P_{IR} + 0.5P_{AE}$ $P_{seis} = 0.5P_{IR} + P_{AE}$ $P_{seis} = P_{IR} + P_a$	Up to 2”	Displacement analysis is not needed.
	$\frac{1}{3}k_{h0} \leq k_h < \frac{1}{2}k_{h0}$	$P_{seis} = P_{IR} + P_{AE}$	Up to 5”	A simplified form of Newmark Sliding Block Method as described in AASHTO CA BDS (AASHTO, 2017; Caltrans, 2019b) can be used.
	$k_h < \frac{1}{3}k_{h0}$	$P_{seis} = P_{IR} + P_{AE}$	Case-by-case depending on relationship between k_h and wall movement	A simplified form of Newmark Sliding Block Method as described in AASHTO CA BDS (AASHTO, 2017; Caltrans, 2019b) can be used.
Advanced numerical methods	Loads on ERS and displacement/ deformation is obtained directly from the advanced numerical analysis.			

Notes:

- k_h= Horizontal seismic acceleration coefficient
- P_a = Resultant (static) active lateral earth pressure force per unit width of ERS (kips/ft)
- P_{AE}= Resultant (seismic) active lateral earth pressure force per unit width of ERS (kips/ft)
- P_{IR}= Horizontal inertial force per unit width of ERS (kips/ft)

11.29.6 REFERENCES

1. AASHTO. (2017). *AASHTO LRFD Bridge Design Specifications*, 8th Edition, American Association of State Highway and Transportation Officials, Washington DC.
2. Caltrans. (2019a). *Caltrans Seismic Design Criteria*, Version 2.0, California Department of Transportation, Sacramento, CA.
3. Caltrans. (2019b). *California Amendments to AASHTO LRFD Bridge Design Specifications*, Eighth Edition, California Department of Transportation, Sacramento, CA.
4. Caltrans. (2020). *Displacement Estimate in Newmark Sliding Block Analysis – A Position Paper.* Department of Transportation, Sacramento, CA.