



Seismic Overall Slope Stability

This module presents the standard of practice for evaluating the seismic overall slope stability of slopes.

Investigation

Refer to the applicable module for investigative practices.

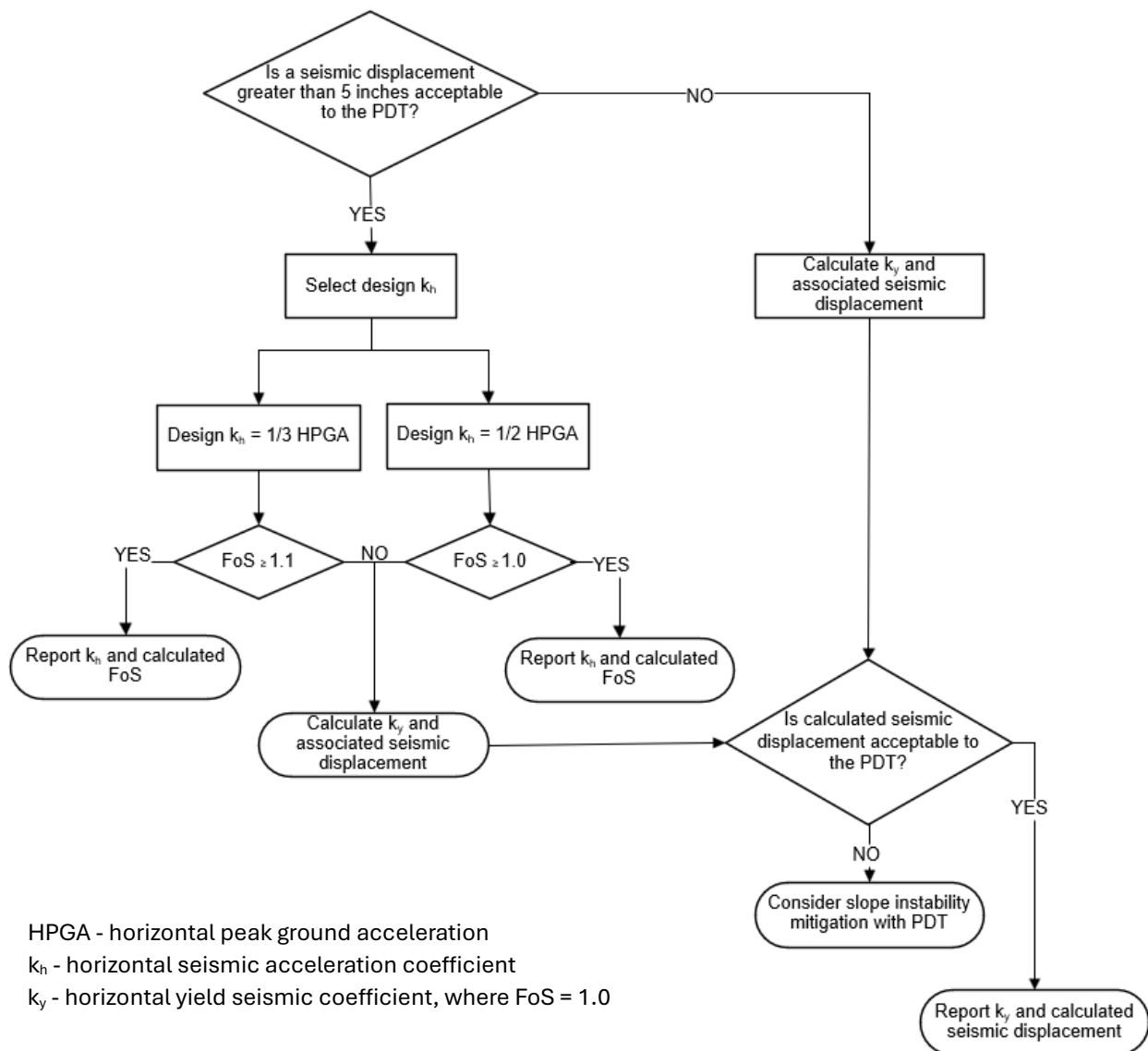
Analysis and Design

The performance criteria for seismic global slope stability should be discussed during the initial (Phase 0) stage of project development with the project team (including district project design engineers and/or bridge designers), as it can vary depending on several factors, including:

- The type of structure or slope involved, such as a retaining wall, bridge abutment, bridge approach, embankment, or cut slope.
- The presence of utilities, buildings, or roadways within the potential slope failure mass.
- The impact of permanent displacement on the project.

If the project team determines that permanent seismic slope displacements greater than 5 inches are unacceptable (e.g., proximity to utility), a project-specific Seismic Displacement Analysis (SDA) should be conducted following the procedure in the Appendix.

If the project team determines that permanent seismic slope displacements greater than 5 inches are acceptable, evaluate seismic overall slope stability following *2017 AASHTO 11.5.8 and C11.5.8*. A performance-based seismic slope stability and required minimum factor of safety (FoS) are provided in the following flow chart. If the required minimum FoS is not met a project-specific SDA should be conducted.



Seismic Overall Slope Stability Analysis Flow Chart



Reporting

Present seismic overall slope stability recommendations in accordance with the *Geotechnical Design Report* module or *Foundation Report for Earth Retaining Systems* module.

Include the following in the *Recommendations* section of the Preliminary Geotechnical Design Report, Geotechnical Design Report, Preliminary Foundation Report, or Foundation Report:

- The design horizontal seismic coefficient (k_h).
- The calculated yield horizontal seismic coefficient (k_y) and permanent seismic displacement, if applicable.
- The Factor of Safety (FoS) and resistance factor ($1/\text{FoS}$).

**Appendix: Permanent Seismic Displacement for Embankments**

When the calculation of permanent seismic displacements is needed, use AASHTO A11.5 which presents three different methods to estimate the seismic displacement using horizontal seismic acceleration coefficient and vice versa. Because Caltrans uses ARS Online webtool for seismic ground motions and response spectra, some parameters used in the methods presented in AASHTO A11.5 need to be modified:

A11.5.1 – Kavazanjian et al. (1997)

For Equation A11.5.1-1, use k_y for k_h and HPGA for A_s .

A11.5.2 –Anderson et al. (2008)

For Equations A11.5.2-1 and A11.5.2-3, use HPGA/g for k_{h0} with a wave scattering factor (α) of 1.0. The wave scattering effect has not been used in Caltrans GS practice and may not be significant for most embankments. If there is a need to consider the wave scattering effect on k_h , use Equation A11.5.2-2 with a site class adjustment factor (F_v) of 1.0. The site class adjustment factor shall be set as 1.0 for all applicable equations as the ARS Online webtool generates an ARS curve that reflects site conditions using a time-averaged shear wave velocity for the upper 30 meters of the soil profile, V_{s30} . For details on how to use the ARS Online webtool, refer to the *Design Acceleration Response Spectrum Module*.

A11.5.3 –Bray et al. (2010) and Bray and Travasarou (2009)

For $T_s < 0.05$ second – treat the potential sliding mass as a block and use $T_s = 0$:

$$d \text{ (cm)} = \exp(-0.22 - 2.83 \ln(k_y) - 0.33(\ln(k_y))^2 + 0.566 \ln(k_y) \ln(\text{HPGA}) + 3.04 \ln(\text{HPGA}) - 0.244(\ln(\text{HPGA}))^2 + 0.278(M - 7))$$

For $T_s \geq 0.05$ second:

$$d \text{ (cm)} = \exp(-1.10 - 2.83 \ln(k_y) - 0.33(\ln(k_y))^2 + 0.566 \ln(k_y) \ln(S_a) + 3.04 \ln(S_a) - 0.244(\ln(S_a))^2 + 1.5T_s + 0.278(M - 7))$$

Where:

T_s : Fundamental period of the embankment

M : Moment magnitude of the design earthquake

S_a : Spectral acceleration (5% damping) at a degraded period of $1.5T_s$

To determine M and S_a , use [ARS Online](#). To calculate T_s , use the following equation:

$$T_s = 4H'/V_s$$



Where:

H' : 80 percent of the height of the embankment measured from the bottom of the embankment

V_s : Shear wave velocity of the embankment soil

Note that AASHTO Equation A11.5.3-1 is basically the same as the equation for $T_s \geq 0.05$ second above but expressed in terms of k_y that is replaced by k_h . AASHTO Equation A11.5.3-1 is typically used to calculate a horizontal seismic acceleration coefficient given the acceptable permanent seismic displacement of the embankment.