Multi-Period Spectra

Charlie Kircher
Kircher & Associates
Palo Alto, California
Design Response Spectrum
(Figure 11.4-1, ASCE 7-10 with annotation)

\[ S_{DS} = \frac{2}{3} S_{MS} = \frac{2}{3} F_a S_s \]

\[ S_{D1} = \frac{2}{3} S_{M1} = \frac{2}{3} F_v S_1 \]

\[ C_s = \frac{S_{DS}}{R/I_e} \quad T \leq T_s \]
\[ C_s = \frac{S_{D1}}{T(R/I_e)} \quad T_s < T \leq T_L \]

\[ T_s = \frac{S_{D1}}{S_{DS}} \]

\[ S_a = \frac{S_{D1}}{T} \]
\[ S_a = \frac{S_{D1} T_L}{T^2} \]
Example ELF “Design Spectrum” based on ASCE 7-16 Criteria
M7.0 earthquake ground motions at $R_x = 6.5$ km, Site Class C
Example ELF “Design Spectrum” based on ASCE 7-16 Criteria
M7.0 earthquake ground motions at $R_x = 6.5$ km, Site Class D
Example ELF “Design Spectrum” based on ASCE 7-16 Criteria

M7.0 earthquake ground motions at $R_x = 6.5$ km, Site Class E

![Graph showing response spectral acceleration vs period for different spectra including MCEr Multi-Period Response Spectrum - Site Class BC, MCEr Multi-Period Response Spectrum - Site Class E, Design Multi-Period Response Spectrum - Site Class E, and ELF Design Spectrum (Cs x R/Ie) - Current ASCE 7-16 Criteria.](#)
Root Cause of the “Problem”

- Section 11.4 of ASCE 7-10 (ASCE 7-16) - Use of only two response periods (0.2s and 1.0s) to define ELF (and MRSA) design forces is not sufficient, in general, to accurately represent response spectral acceleration for all design periods
  - Reasonably Accurate (or Conservative) – When peak $MCE_R$ response spectral acceleration occurs at or near 0.2s and peak $MCE_R$ response spectral velocity occurs at or near 1.0s for the site of interest (i.e., frequency content matches the shape of the design response spectrum, Figure 11.4-1)
  - Potentially Non-conservative – When peak $MCE_R$ response spectral velocity occurs at periods greater than 1.0s for the site of interest (e.g., soil sites whose seismic hazard is dominated by large magnitude events)
Short-Term Solution Options (ASCE 7-16)

- Re-formulate seismic parameters to eliminate potential non-conservatism in ELF (and MRSA) seismic forces
- Require site-specific analysis when ELF (and MSRA) seismic forces could be potentially non-conservative
ASCE 7-16 Short-Term Solution to Potential Underestimation of ELF (and MSRA) Seismic Design Forces

• **Temporary Solution.** The new site-specific design requirements of Section 11.4.7 provide a short-term solution that can and should be replaced by a more appropriate long-term solution in the next Code cycle.

• **Multi-Period Design Spectra.** A long-term solution would necessarily include seismic criteria described by multi-period MCE$_R$ response spectra.

• **Design Spectrum Shape.** Ideally, multi-period design spectra would directly incorporate site, basin and other effects that influence the shape (i.e., frequency content) of the design spectrum.
Summary of Multi-Period Spectra Issue

• Develop and adopt multi-period design spectrum approach

• Risks - Multi-period spectrum approach would require:
  – Major reworking of seismic design requirements and criteria now based on two response periods (e.g., Tables 11.6-1/2, Seismic Design Categories, etc.)
  – Development of new ground motion design values maps (by the USGS) for each new response period of interest
  – Development of new site factor tables for each new response period of interest (or site effects embedded directly in ground motion design values maps)

• Resources – Major, multi-year projects by USGS and a Seismic Code-development team(s)