Non-Causal Zero-Phase Filters Underpredict NGA 2 GMPE’s for Long-Period, Near-Source Motions of Large Earthquakes

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The Lucerne record from the 1992 M7.3 Landers earthquake had motions too large to be accommodated by the San Bernardino Law and Justice Center. This is problematic because this structure was designed for maximum ground motion with triple pendulum base isolators. We investigated the predictions for 10-second response spectral displacements and found that NGA 2 GMPEs under-predict, specifically long-period, near-source motions from large earthquakes. The under-prediction may be due to the conventional data processing method used in the NGA ground-motion database, which is a non-causal zero-phase Butterworth filter at a corner frequency corresponding to the expected level of noise in the record.

Theoretically, a non-causal zero-phase filtered response is approximately half the value of the response with no filter. We can see this by filtering a unit step function, in which we get a response with half the amplitude of the original, unfiltered function. While non-causal zero-phase filtering leaves the acceleration unchanged, the effect of the corner frequency in this filtering is noticeable when we integrate twice to obtain the displacement. Therefore, because long period components of the recorded ground motion may contain valuable information, it is critical to choose the appropriate period of the non-causal zero-phase filter.

We examine the strong motion data from large earthquakes, such as the 1999 M7.7 Chi-Chi, 2015 M7.8 Nepal, 2016 M7.0 Kumamoto, and 2016 M7.8 New Zealand earthquakes. We apply the baseline correction to the uncorrected acceleration records, in which we account for the linear trend in velocity. Then, we integrate for the peak displacement. The same process is applied to the acceleration records that are non-causal zero-phase filtered at 10 seconds and 60 seconds. We compare the baseline corrected displacement responses of these earthquakes to the filtered ones. Ultimately, we take these broadband ground motion records containing long period effects, conduct both linear and nonlinear response analyses of tall buildings, and observe how static offset affects these responses.

