Report of the SCEC Utilization of Ground Motion Simulations (UGMS) Committee Accomplishments during 2015

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Introduction

The goal of the UGMS committee, since its inception in the spring of 2013, has been to develop long-period response spectral acceleration maps for the Los Angeles region for inclusion in NEHRP and ASCE 7 Seismic Provisions and in Los Angeles City Building Code. The maps are to be based on 3-D numerical ground-motion simulations, and ground motions computed using latest empirical ground-motion prediction equations from the PEER NGA project. The work of the UGMS committee is being coordinated with (1) the SCEC Ground Motion Simulation Validation Technical Activity Group (GMSV-TAG), (2) other SCEC projects, such as CyberShake and UCERF, and (3) the USGS national seismic hazard mapping project. Continued progress toward developing the maps was made in 2015, and this summary report highlights the accomplishments and future work.

Background and Motivation for Long Period Ground Motion Maps

Section 11.4 in the current ASCE 7-10 (and forthcoming ASCE 7-16) standard specifies a general procedure for developing risk targeted Maximum Considered Earthquake (MCE_R) response spectral accelerations at intermediate and long periods. These long period accelerations depend on two parameters, S_{M1} and T_L, where S_{M1} is the MCE_R response spectral acceleration at 1-sec period that accounts for the effect of the local site geology through the site coefficient, F_v, and T_L is the period that defines the transition in the MCE_R spectrum from constant spectral velocity to constant spectral displacement.

The T_L parameter was introduced in the ASCE 7-05 standard to provide a more realistic estimate of the response spectrum at long periods. The values of T_L vary from 4 sec to 16 sec depending on location in the US. During its development, deficiencies in the T_L concept were recognized, but a better representation of the long period motions was not possible at the time because the existing ground motion prediction equations (GMPEs) did not extend to long periods.

The subsequent NGA West and NGA West2 projects, culminating in 2008 and 2013, produced GMPEs for computing response spectra to 10-sec period from shallow crustal earthquakes in the western US. Although these GMPEs were derived from an extensive world-wide ground-motion database, relatively few truly strong ground motion records in this database were from earthquakes in the Los Angeles area, where the effects of the complex 3-D basin structures were known to have significant influences on long period motions. Furthermore, the earthquakes on the local faults contributing to the MCE_R motions in Los Angeles have not occurred during the last several decades when the region was populated with arrays of strong motion instruments.

The available ground motion data for southern California did suggest a correlation between long period ground motions and basin depth. Thus, NGA West, NGA West2, and a few previous generation GMPEs incorporated a basin depth term to model the effect of the basins. However, this parameterization ignores the 3-D effect, as well as the location and orientation of the fault rupture with respect to the basins. Recognizing this deficiency in the empirical GMPEs, SCEC launched a program to simulate ground motions numerically using a physics-based 3-D fault-rupture and wave-propagation model of Southern California. The computations were done with the CyberShake platform that utilized supercomputers to generate millions of simulations covering the range of potential moderate to large magnitude earthquakes on Southern California faults included in the Uniform California Earthquake Rupture Forecast (UCERF) models the USGS has used to develop the MCE_R ground-motion maps for the region.

The potential feasibility of using CyberShake to develop long period ground motion maps was demonstrated by SCEC (Graves et al., 2010; Wang and Jordan, 2014), and this eventually led to the formation of the SCEC UGMS committee.

Results Generated by UGMS during 2015

During its May 2015 meeting, the UGMS committee proposed a preliminary approach to combine the results from the NGA West2 GMPE's with those from CyberShake. The approach is illustrated in the logic tree shown in Figure 1. To determine the MCE_R response spectra, the probabilistic and deterministic seismic hazard analyses (PSHA and DSHA), per procedures in Chapter 21 of ASCE 7-10, would use both the NGA West2 and CyberShake as GMPEs, but the weights assigned to each would vary depending on the natural period, with the NGA West2 GMPEs receiving all the weight for periods, $T \leq 1.0$ sec. As T increased, the weights for the NGA West2 GMPEs would decrease and the weight for the CyberShake motions would increase; for $T \geq 5.0$ sec, the weights would be equal. The weights can be applied to either the hazard curves from the PSHA or to the probabilistic MCE_R response spectra from each GMPE set (NGA West2 and CyberShake).

The MCE_R response spectrum, resulting from a geometric averaging of the probabilistic MCE_R response spectra, is shown for the p22 (San Fernando Valley), CCP (Century City Plaza), COO (Compton), and s429 (Carson) sites (see Figure 2 for site locations) in Figures 3 through 6. The first two sites are at the edge of basins, while the last two are in the deep part of the Los Angeles basin. These four sites are among the 14 sites that were chosen in 2014 to test the feasibility of CyberShake for generating realistic MCE_R response spectra. The locations of all 14 sites are shown in Figure 7, which also lists the site values of Vs30, the average shear-wave velocity in the upper 30m, and the basin depth term, $Z_{1.0}$ or $Z_{2.5}$, the depth to the top of the layer with a shear-wave velocity of 1 km/sec or 2.5 km/sec, respectively.

Each of the 14 plots following Figure 7 shows the MCE_R response spectrum (curved green line labeled “Avg. MCEr”) resulting from the weighted averaging of the NGA West2 and

CyberShake total mean hazard curves. Also shown on each plot are (1) the individual MCE_R response spectra from the NGA West2 GMPEs (curved red line labeled "GMPE MCEr") and CyberShake (curved purple line labeled "CyberShake MCEr"), (2) the MCE_R response spectrum from the S_{MS} and T_L values obtained from the Beta version of the USGS web look-up tool for the forthcoming ASCE 7-16 standard (upper horizontal straight line from 1-sec to T_L labeled "ASCE 7-16 MCEr"), and (3) the Deterministic Lower Limit Spectrum (lower horizontal straight line from 1-sec to T_L), from ASCE 7-10 .

From the results presented above, some smoothing of the MCE_R response spectra would be required, regardless of which weighting scheme is selected. The UGMS committee will plan to decide on the weights and weighting scheme in 2016.

Recognizing that CyberShake underestimated response spectra at $T < 2$ sec, a hybrid, broadband approach (Graves and Pitarka, 2010) for extending the CyberShake-based MCE_R response spectra to shorter periods, was presented at the November UGMS meeting. This approach and its possible utility will be considered further in 2016.

Conclusions and Work Planned for 2016

The results generated during 2015 continue to be encouraging and indicate that the UGMS committee should continue its efforts toward generating long period ground motion maps for Southern California. The immediate goal is possible inclusion of the maps in the next edition of the Los Angeles City building code, which would be a variation to the ground motions for Southern California in the ASCE 7-16 standard.

A few technical issues will need to be addressed before draft maps can be prepared. One item is local site response. New results from site-response analysis (SRA) for the Carson site were presented by D. Asimaki at the November 2015 UGMS meeting, and additional SRA were suggested at other sites, before deciding on the approach to handle the effects of the upper 100-m layer on the surface motions. One suggested method was to provide the outcrop MCE_R response spectrum at 100-m depth at all grid locations, so that consultants would have the option of conducting SRA using the results of geotechnical and geophysical investigations at a particular site of interest.

The UGMS committee must also finalize the method to (1) combine the CyberShake simulations and the results using the NGA West2 GMPE's to generate the MCE_R maps, and (2) produce smooth MCE_R response spectra for engineering use. Once accomplished (planned for the first half of 2016), members of the UGMS will contact the Structural Engineers Association of Southern California (SEAOSC) to present the UGMS goals, procedures and results. The UGMS recognized the importance of obtaining the backing of SEASC if our proposal to introduce MCE_R maps as amendments to the maps in ASCE -16 for the Los Angeles region is to be accepted by City building code officials. The "maps" envisioned are electronic, and MCE_R

response spectra at given locations would be obtained from a USGS-like web look-up tool, in which users would input the site coordinates and site class (or Vs30) and output would be the MCE_R response spectra. The tool would be developed by SCEC with input from the UGMS and assistance from the USGS. The plan is to start the development in the first half of 2016 with a trial version completed toward the end of 2016.

Additional verification studies of the CyberShake simulations against data recorded during recent small magnitude earthquakes in Southern California are also planned for 2016.

References

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