THE SCEC BROADBAND PLATFORM AND CYBERSHAKE: COMPREHENSIVE EARTHQUAKE GROUND MOTION SIMULATION TOOLS FOR ENGINEERING APPLICATIONS

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As part of the design process, numerous engineering applications require seismic time series as input to soil and structural models to simulate their response. Although recorded earthquake ground-motion (GM) datasets are constantly being compiled and updated over time, there are still only a limited number of records available for large magnitude events (M≥7) recorded in the near field (within 20 km of the fault rupture). Additionally, other source-site effects, such as hanging-wall or rupture directivity, have not been captured by many of these recorded motions. Because of these limitations, simulated ground motions can provide otherwise unavailable information. However, it is essential to carefully validate ground motion simulations before those can be confidently used for engineering purposes.

Over the last decade, the Southern California Earthquake Center (SCEC) has developed several software tools for simulating ground motions. We present an overview of two products geared towards engineering applications: the Broadband Platform (BBP) and CyberShake, a physics-based probabilistic and deterministic seismic hazard analysis (PSHA and DSHA) simulation tool. Together, the BBP and CyberShake model a wide range of complexities in the fault rupture, wave propagation, and 3-D regional geology. Both platforms produce time series from which various engineering intensity measures are computed. Extensive validation exercises are being completed by teams of scientists and engineers at SCEC to ensure that those simulations are suitable for engineering applications.

The BBP is an open-source software package developed to simulate broadband (0-100 Hz) GM waveforms using a variety of scientific modules that model source, path and site effects. The current implementation of the BBP includes source modules relying on kinematic rupture generators. The wave propagation is performed through 1-D layered velocity structures. These simplifications make the BBP a resource-efficient tool, ideally suited for a relatively large number of runs, which supports sensitivity studies and uncertainty estimations. The BBP was used recently in the Pacific Earthquake Engineering Research center (PEER) NGA-West2 and NGA-East projects to support ground-motion model (GMM) development and by the Southwestern U.S. (SWUS) project as part of the site-specific analysis of the Diablo Canyon Nuclear Power Plant. We present an overview of the platform and summarize a suite of recent validation exercises.

CyberShake utilizes 3D simulations and finite-fault rupture descriptions to compute GMs for PSHA and DSHA. CyberShake 3D deterministic wave propagation simulations can account for complex effects such as the coupling of directivity and basin response that cannot easily be captured with standard approaches. However, computational demands are intense, requiring parallel algorithms and high throughput workflows to be executed on high-performance computer clusters. Going beyond traditional hazard analysis, event-specific phenomena can also be identified and analyzed through examination of the individual GM waveforms. This process highlights the importance of key elements in the simulation
approach, including the consideration of aleatory variability and epistemic uncertainty of various parameters and spatio-temporal rupture characterizations. Using simulation-based and traditional empirical-based approaches, the SCEC Committee for Utilization of Ground Motion Simulations (UGMS) is working to develop improved response spectral acceleration maps for the Los Angeles region for possible future inclusion in the NEHRP and ASCE 7 Seismic Provisions and the Los Angeles City Building Code. We present an overview of CyberShake as well as draft products from the UGMS efforts.