Research Project Highlight

Stochastic Modeling and Simulation of Near-Fault Ground Motions for use in PBEE

Project # 1127-NCTRAR

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Abstract
This project is an extension of the research conducted under previous PEER funding [1, 2] on stochastic modeling and simulation of near-fault ground motions. We developed a site-based parameterized stochastic model of the near-fault ground motion in two orthogonal horizontal directions and presented a practical method of generating synthetic near-fault ground motions for specified earthquake source and site characteristics that are readily available to design engineers. As shown in the *Project Image,* this method accounts for the rupture directivity effect and produces pulse-like and non-pulse-like ground motions, in accordance with their observed proportions among recorded near-fault ground motions. The method accounts for temporal and spectral non-stationarity and for the variability inherent in real earthquake ground motions.

With a simple form, a small number of parameters, and a limited dataset to which it was fitted, the current model is not able to capture all characteristics of recorded near-fault ground motions. Therefore, in this study, the existing model will be scrutinized and ways to improve its formulation investigated, with focus on those components that most influence structural response. The ground motion characteristics that we will attempt to improve include correlations between spectral values at different periods and variability in spectral accelerations at long periods. The improved formulation will better characterize the level of ground shaking in seismic performance assessment and design of long-period structures, such as tall buildings and long-span bridges.

The research will also facilitate use of the simulation procedure for practicing engineers. The methods of computing the modulating function parameters will be improved; the size of the generated time series

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data will be reduced to make ensuing structural response calculations more tractable; and users will be given more flexibility in the specification of the input, e.g., by adding an option to generate ground motions for randomized hypocenter locations.

Deliverables

A PEER report and several conference and journal papers describing the improved stochastic models and simulation procedure for pulse- and non-pulse-like near-fault ground motions; a MATLAB software based on the improved stochastic model and simulation procedure to generate synthetic near-fault ground motion time series for specified earthquake source and site characteristics.

Research Impact

This project contributes to the first step of PEER's performance based earthquake engineering (PBEE) methodology, namely, characterization of the seismic hazard at a location of interest with a special focus on near-fault sites. Near-fault ground motions may possess distinct characteristics, including the rupture directivity effect that should be taken into account in the seismic risk and performance assessment of structures located nearby active faults.

Probabilistic seismic hazard analysis (PSHA) can be conducted by combining the proposed ground motion model and simulation procedure to seismic source characterization. This first step of PBEE is crucial for the ensuing steps of computing structural responses for the given hazard, defining and computing relevant measures of damage to structural and non-structural components and equipment, and computing decision variables that relate to casualties, cost, and downtime. These decision variables drive performance-based design of structures, rendering careful characterization of ground motions essential. Thus, we believe the results of this project will fill an important gap in the practice of PBEE.

By improving the existing near-fault ground motion model and simulation procedure, the research being conducted will facilitate the use of simulated ground motions in PBEE. Specifically, for any set of earthquake source and site characteristics, one can generate realistic simulated near-fault ground motions which have similar statistical characteristics as recorded motions in the NGA West2 database. These simulated motions can be used in response history analysis and in PBEE applications, in place of or in addition to recorded ground motions, without any need for scaling which is a questionable practice in many instances. For example, the outcome of this research can be used to characterize the level of ground shaking in the seismic performance assessment or design of long-period structures, such as tall buildings and long-span bridges in near-fault regions.

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Project Image

Input: $F = 0, M_w = 7, Z_{TOR} = 0$ km, $R_{RUP} = 10$ km, $V_{s30} = 760$ m/s, $s_{or}d = 40$ km, $\theta_{or}\phi = 14°$
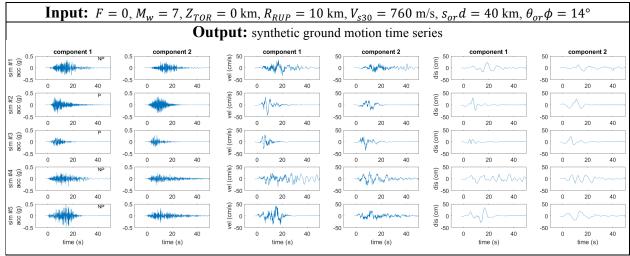
Output: synthetic ground motion time series

Illustration of the simulation procedure:

a) The required input is limited to the type of faulting F, earthquake magnitude M_w, depth to the top of the rupture plane Z_{TOR}, closest distance from the site to the rupture plane R_{RUP}, shear-wave velocity at the site V_{S30}, and directivity parameters $s_{or}d$ and $\theta_{or}\phi$.

b) Sample of five simulated pulse-like (P) and non-pulse-like (NP) near-fault ground motion components in two orthogonal horizontal directions for prescribed earthquake source and site characteristics $F = 0, M_w = 7, Z_{TOR} = 0$ km, $R_{RUP} = 10$ km, $V_{s30} = 760$ m/s, $s_{or}d = 40$ km, $\theta_{or}\phi = 14°$: acceleration, velocity, and displacement time series.

References

1. Dabaghi M, Der Kiureghian A. Stochastic modeling and simulation of near-fault ground motions for performance-based earthquake engineering, *PEER Report No. 2014/20,* Pacific Earthquake Engineering Research Center, University of California, Berkeley, CA, 2014.

2. Dabaghi M, Der Kiureghian A. Stochastic model for simulation of near-fault ground motions. *Earthquake Engineering & Structural Dynamics* 2017; **46** (6): 963-984. 10.1002/eqe.2839.