COMPARISON OF RECORDED AND SIMULATED GROUND MOTIONS FOR TALL BUILDINGS

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Abstract

Seismic hazard for tall buildings in California is often dominated by large magnitude earthquakes for which few recorded accelerograms are available for response history analysis. In several recent manuscripts, we compare motions for an M_w 7.8 event on the southern San Andreas fault (known as the ShakeOut event), two ShakeOut permutations with different hypocenter locations, and a M_w 7.15 Puente Hills blind thrust event beneath downtown Los Angeles, to median and dispersion predictions from the empirical NGA ground motion prediction equations. The dispersion is represented by an intra-event standard deviation term, which is lower than NGA values at low periods and abruptly increases at 1.0 sec due to different simulation procedures at low and high periods. The simulated motions attenuate faster with distance than is predicted by the NGA models for periods under approximately 5.0 sec. This suggests ground motions away from the fault rupture are under-predicted by the simulation. After removing distance attenuation bias, we have found average residuals of the simulated events (i.e., event terms) are generally within the scatter of empirical event terms, indicating that the ShakeOut event is not unusually energetic for its magnitude. The simulated motions have a depth-dependent basin response similar to the NGA models, but also show complex effects in which stronger basin response occurs when the fault rupture transmits energy into a basin at low angle. The motions also indicate rupture directivity effects that scale with the isochrone parameter.

Introduction

This article is a brief overview of materials that have been submitted for publication elsewhere (Star et al., 2010a, 2010b).

Simulated ground motions have the potential to provide a valuable supplement to empirical methods, especially for large magnitudes and close site-source distances (e.g., M_w > 7.5 and distance < 20 km) for which recordings are sparse, especially for strike-slip earthquakes. In southern California, the design of duration-sensitive or long-period structures is often controlled by magnitude ~7.8-8.2 earthquakes on the southern San Andreas fault. There are very few recorded accelerograms that can be used for response history analysis for such conditions.

Simulation procedures that capture complex source features, path effects, and site effects can help fill this need. However, such techniques have not found significant practical applications to date in the western United States because of a general sense among engineers that the simulated motions have not been adequately validated. This, then, raises the issue of how simulated motions *should* be validated.

Star et al. (2010a) present a procedure that checks key attributes of simulated motions relative to empirical observation, as represented by appropriate GMPEs. The procedure is appropriate for use with simulated motions that are both broad-band (i.e., span the range of periods of engineering interest) and are based on a simulation procedure that considers essential earthquake physics (i.e., source, path, and site processes). The Shakeout project (Jones et al., 2008) provides a convenient test case, as the motions for the M_w 7.8 earthquake on the southern San Andreas fault have the above attributes Using motions from the ShakeOut event and other events, Star et al. (2010a) evaluate specific attributes critical to ground motion hazard analysis, including site-to-site variability, distance attenuation, source energy, basin response, and directivity effects. Star et al. (2010b) discuss the basin response and directivity effects in more detail.

Overview of Major Findings

Star et al. (2010a) investigate the degree to which the ground motions produced by simulations of major earthquakes on the San Andreas and Puente Hills faults are consistent with respect to specific attributes of NGA ground motion prediction equations (GMPEs), including source scaling, distance attenuation, and dispersion. They compare the intensity measures (peak acceleration, peak velocity, and spectral acceleration) with those predicted using the NGA GMPEs.

Analyses of intra-event residuals shows faster distance-attenuation of the simulated data relative to the GMPEs. This was interpreted as a shortcoming of the existing simulation routine that will be addressed in future research. They modify the GMPE distance parameters in order to match the distance attenuation of the synthetic models so that distance-bias is not mapped into the analysis of other effects. Using the modified GMPEs, they then perform a general comparison of the overall synthetic ground motions to the average ground motions predicted using the GMPEs for events of the same magnitude. This is accomplished through the analysis of event terms (inter-event residuals), which represent the average offset of the data (in this case, from the simulations) from a median model prediction (from the modified GMPE). They find that the event terms, while non-zero, are generally within a reasonable range relative to actual event terms from past earthquakes.

Star et al. (2010a) then examine the intra-event standard deviation to investigate the amount of scatter between different recordings of the same earthquake. They find that for short periods, the intra-event standard deviation values calculated from the simulated data are low compared to those given by empirical models. This indicates that the simulated models underpredict dispersion relative to GMPEs. There is a significant jump in the intra-event standard deviation values at about T=1.0s that results from different simulation procedures at short and long periods. They interpret both the low dispersion at short periods and the jump as additional shortcomings in the simulation procedure that will be addressed in subsequent work.

Star et al. (2010a, 2010b) performed additional analysis of residuals from the modified GMPEs provided insights into basin and directivity effects. They generally observe ground motion increases with depth within basins, but also find complex interactions between basins and fault rupture. Among the most significant of those interactions are relatively strong motions within basins that open to the fault at low angle (i.e., when waves traveling along the fault strike can enter a basin with a small to modest “turn,” the basin response is strong). For rock sites, directivity effects at close distance (R_{rup} < 40 km) scale with the isochrone parameter in a manner similar to the Spudich and Chiou (2008) model. However, the coupling of basin and directivity effects described above often leads to average residuals within basins that are more strongly positive or negative than would be predicted by existing empirical models. It is not clear whether these differences reflect shortcomings in the empirical models or peculiarities in the simulated motions.

References

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