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SELECTION OF CYBERSHAKE TIME SERIES FOR ENGINEERING BUILDING CODE ANALYSES

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ABSTRACT

This paper presents results from a project to search the CyberShake ground motion simulation catalog in order to select suites of ground motions that satisfy building code requirements and could be used to evaluate a tall building design at several potential sites in Los Angeles. The search and selection of ground motions provides an understanding of the suitability of CyberShake ground motions for practical engineering analysis. Comparable suites of recorded ground motions are selected for the same sites, in order to illustrate the relative advantages and disadvantages of using the two data sources. A number of ground motion metrics, including directional polarization and shaking duration, are evaluated for the suites of simulations, in order to evaluate their reasonableness for representing future earthquake shaking. In summary, the results provide further insights regarding the value of physics-based ground motion simulations for use in engineering analyses.

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Selection of CyberShake Time Series for Engineering Building Code Analyses

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ABSTRACT

This paper presents results from a project to search the CyberShake ground motion simulation catalog in order to select suites of ground motions that satisfy building code requirements and could be used to evaluate a tall building design at several potential sites in Los Angeles. The search and selection of ground motions provides an understanding of the suitability of CyberShake ground motions for practical engineering analysis. Comparable suites of recorded ground motions are selected for the same sites, in order to illustrate the relative advantages and disadvantages of using the two data sources. A number of ground motion metrics, including directional polarization and shaking duration, are evaluated for the suites of simulations, in order to evaluate their reasonableness for representing future earthquake shaking. In summary, the results provide further insights regarding the value of physics-based ground motion simulations for use in engineering analyses.

Introduction

Ground motion records are used as inputs for seismic structural analysis and design. Past earthquakes, as preferred by many building codes, serve as the main data source of records for dynamic seismic analysis for design of structures. Considerable efforts have been taken in ground motion simulation, with different methodologies developed, including stochastic [e.g., 1] and hybrid [e.g., 2] approaches. The potential benefit of simulations is to provide data for infrequent situations, such as large magnitude events, records on rock sites and regions with low seismicity. However, simulated ground motions should be validated to ensure that they have similar characteristics as records from real earthquakes before using them in design and analysis. This study aims to evaluate the suitability of simulated ground motions from CyberShake for engineering application in Los Angeles region. An engineering practice-oriented validation was conducted using two data sources, CyberShake and NGA-West2. According to ASCE 7-16 requirements, 11 comparable ground motion records were selected from each source for the same sites in Los Angeles. Several ground motion metrics, including deaggregation, duration parameters and directivity, were considered for the suites of simulations. Their consistency with recordings

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from NGA-West2 and empirical models was reviewed.

Ground motion selection

NGA-West2 database and CyberShake serve as data sources for recorded and simulated ground motions, respectively. CyberShake is a physics-based seismic hazard model developed by Southern California Earthquake Center (SCEC). It performs ground motion simulations at about 300 sites with 5km spacing in Los Angeles basin [3]. Considering all ruptures up to 200km from the site of interest, there are around 7,000 ruptures identified [3]. Two sites with different underlying soil condition were chosen. Their information from CyberShake is listed in Table 1. Design spectra for two sites were generated using USGS Seismic Design Maps following ASCE 7-10 building code requirements. 11 records with minimum error were selected to match the target spectrum from period 1s to 7.5s. The error was computed as

$$Error_{selected} = \sum_j \left(\ln\left(Sa_{selected}(T_j)\right) - \ln\left(Sa_{targ}(T_j)\right)\right)^2 \quad (1)$$

where $Sa_{selected}(T_j)$ is the peak response of one selected record at period T_j, and $Sa_{targ}(T_j)$ is the target design spectrum at same period.

When selecting recordings from NGA-West2, Vs30 range was set as ±150m/s of CyberShake values. Scaling of ground motions was applied for NGA-West2 selection, but not for CyberShake.

Table 1. Site names, locations and soil conditions for the two considered sites.

Site name	Latitude	Longitude	Vs30 (m/s)
Los Angeles downtown (LADT)	34.05204	-118.25713	390
Pasadena (PAS)	34.148426	-118.17119	748

Deaggregation

The consistency of selected ground motions with hazard deaggregation is summarized in this section. The first two columns in Figure 1 are deaggregation plots using results from the USGS 2014 hazard model, at periods 1s and 5s, with return period 2475 years. The deaggregation results for sites LADT and PAS are similar. Ground motions are dominated by earthquakes within 20 km, with magnitudes from 6.5 to 8.5. Figures 1(c) and (f) show the magnitudes and distances of the 11 selected ground motions. The distances and magnitudes of the selected ground motions from CyberShake are consistent with deaggregation plots. For site LADT, CyberShake results show large contribution from earthquakes at longer distances (>50km), as illustrated in Figure 1(c). This is also reflected in the 5s period deaggregation plot (Figure 1(b)). The distribution of magnitude and distance for site PAS (Figure 1(f)) has a better consistency with 1s period deaggregation plot (Figure 1(d)), where earthquakes at closer distance (<20km) control the risk. Most of the recorded ground motions match well with deaggregation plots, even though scaling process is implemented during selection. Compared to results from CyberShake, they contain more ground motions with small magnitudes. For site LADT, unlike CyberShake, the distribution (Figure 1(c)) has a better consistency with 1s period deaggregation plot (Figure 1(a)), where earthquakes with a smaller magnitude (< 7) control the risk. For site PAS, compared to Figure 1(d) and (e), magnitude and distance of 4 selected records are inconsistent with deaggregation results, as shown in Figure 1(f).

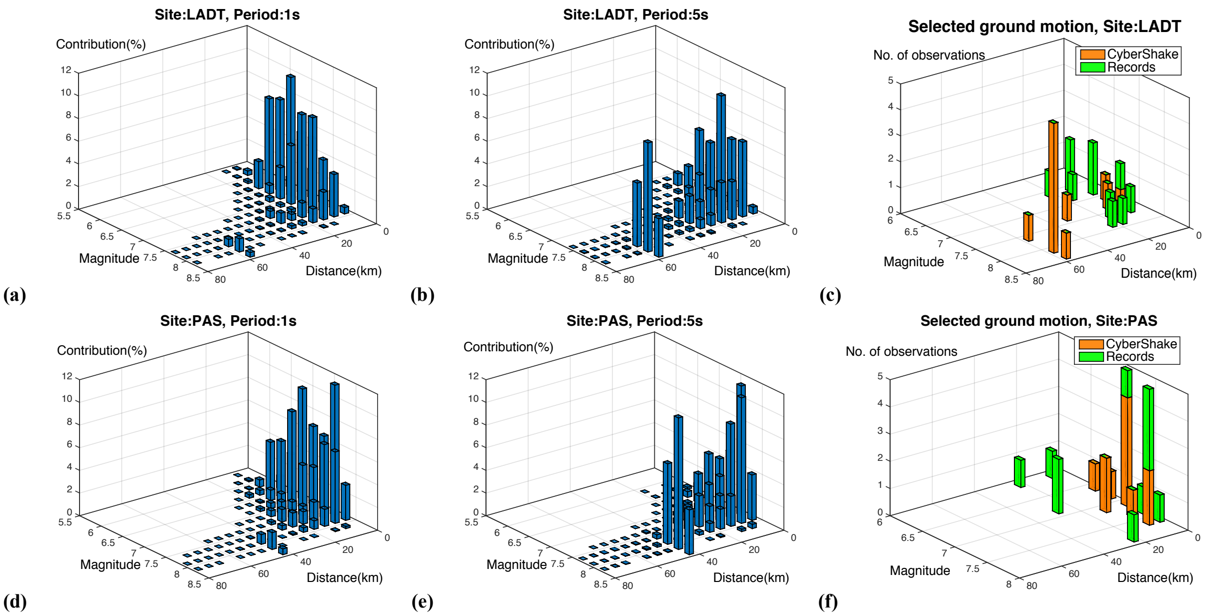

Figure 1. Deaggregation for site LADT at (a) 1s, (b) 5s, (c) magnitude and distance of selected ground motions for site LADT, deaggregation for site PAS at (d) 1s, (e) 5s, (f) magnitude and distance of selected ground motions for site PAS

Duration

We validated significant durations (5% - 75% Arias intensity) generated from CyberShake against that from NGA-West2 and some empirical models. This study employed three empirical models proposed by Afshari and Stewart (2016) [4] (denoted as AS2016), Bommer et al. (2009) [5] (denoted as Bommer2009) and Abrahamson and Silva (1996) [6] (denoted as AS1996). Figure 2 shows the comparison among median duration curves from CyberShake, NGA-West2 and three prediction models with a reference distance of 20km. All curves illustrate the expected trend of larger-magnitude ground motions having longer durations. Durations of ground motions at site LADT agree well with empirical models and recorded data, as shown in Figure 2(a). Given a pair of distance and magnitude, durations at LADT (Figure 2(a)) are longer than those at PAS (Figure 2(b)), indicating the effect of the underlying sedimentary basin. This trend is also reflected in the recordings from NGA-West2 with comparable Vs30 values.

Polarization

Directional polarization is a phenomenon where the ground motion intensity is stronger in some directions than other. The difference in 2 dimensional space is important for engineering design, and cannot be captured by a single response spectrum. In this study, the degree of polarization was quantified as $Sa_{RotD100}(T)/Sa_{RotD50}(T)$, where $Sa_{RotD100}(T)$ is the maximum response in all orientations at a given period, and $Sa_{RotD50}(T)$ is the median value. $Sa_{RotD100}(T)/Sa_{RotD50}(T)$ ranges from 1.0 to $\sqrt{2}$, with a larger value indicating a more polarized response. We computed the geometric mean of $Sa_{RotD100}$ to Sa_{RotD50} ratio for 11 selected ground motions from NGA-West2 and CyberShake. They were plotted in semi-log scale and compared against the average observed values from NGA-West2 model [7], shown in Figure 3. For both sites, the geometric means from both sources have same trend as the average observed ratios, with maximum difference around 0.1. Moreover, higher ratios are observed at longer periods. For site LADT, the CyberShake output has a noticeable increase in ratio from period 0.7s to 1.0s, and it remains relatively constant outside this range. This dependence of frequency may due to the transition from deterministic ground motion simulation methodology to stochastic approach at around 1Hz.

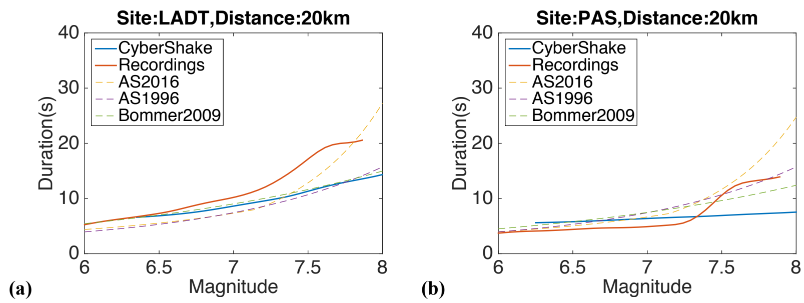

Figure 2. Median duration for (a) site LADT, (b) site PAS

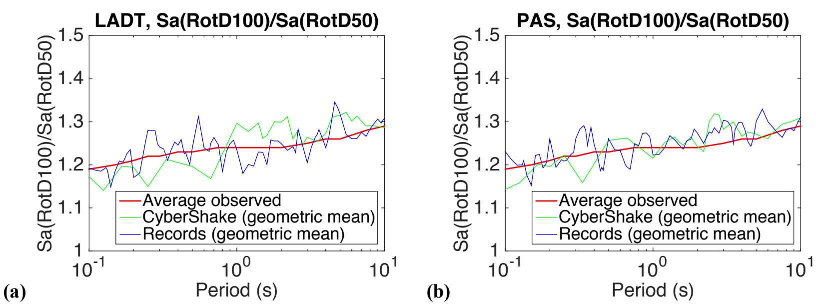

Figure 3. $Sa_{RotD100}(T)/Sa_{RotD50}(T)$ for (a) site LADT, (b) site PAS, compared against the average observed ratio from NGA-West2

Conclusions

This extended abstract serves as a preliminary study for validation of CyberShake ground motions as a tool for engineering analysis. A number of ground motion metrics, including deaggregation, polarization and duration, were discussed in this paper. Based on the presented evaluation, we can conclude that ground motions from CyberShake and NGA-West2 share similar features, in terms of polarization and duration. Deaggregation from CyberShake has better consistency with USGS hazard deaggregation analysis. A potential concern regarding the frequency dependency of spectral polarization in CyberShake ground motions was noted. Continuing work will focus on detailed evaluation of polarization and shaking duration by involving more fault-site pairs. The influence of rupture-site distance, rupture-site orientation and fault geometry on polarization will be further analyzed. In addition, site-specific and source-specific effect on duration and polarization will be explored.

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