Validation of simulated ground motions based on demands imposed on complex structural systems

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1. Motivation

Ground motion simulations offer the potential to significantly improve seismic hazard characterization, however their continued improvement requires extensive validation. While validation is often undertaken based on ground motion intensity measures (spectral accelerations, duration, etc.), it is also critical to examine the consistency of simulated ground motions when compared in terms of the seismic demands imposed on complex structural and geotechnical systems.

Figure 1 shows the validation framework of Bradley et al. (2017) which illustrates the importance of validation in order to develop predictive confidence. The vertical axis indicates the increasing spatial resolution from generic to region and site-specific validation. The horizontal axis indicates the increasing complexity of intensity measure metrics used in quantifying simulation validation, which is a function of the specific engineered system considered. In particular, the fourth column indicates the use of complex MDOF response to validate ground motion simulations in a manner that cannot simply be examined based on the use of simple ground motion intensity measures alone.

The aim of this poster is to examine the seismic response of a realistic structural system when subjected to ground motions for the 22 February 2011 Christchurch earthquake – both those observed at strong motion stations and also simulated at the same locations as documented in Razafindrakoto et al. (2017).

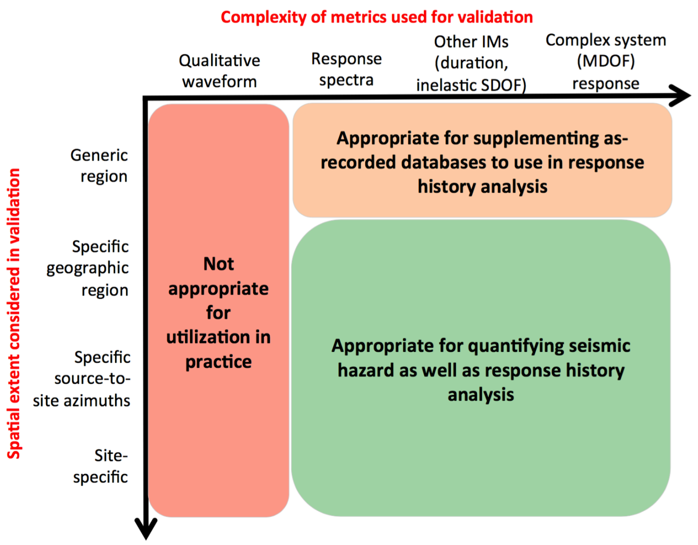

Figure 1: Ground motion simulation validation matrix (Bradley et al. 2017).

2. Structural system considered

The seismic response of a seven-story concrete building is examined here, as an example among the systems considered. This building has a boundary wall system in the North-South direction, shear walls in East-West direction, and moment resisting frames in both directions. The structure is capacity-designed based on the New Zealand concrete seismic design code. Translational vibration periods of the structure in both directions are ~0.5 s. Figure 2 shows a 3D view of this system. Engineering demand parameters considered here are inter-story drift and acceleration at the centre of mass for each floor.

3. Simulated and observed ground motions considered

Figure 3 presents the 5% damped response spectra of the north-south component of the 40 recorded and simulated ground motions considered. As shown, both records have large distributions with respect to 500 years return period design spectrum.

Figure 4 presents the spectral acceleration ratio of the observed and simulated ground motions, indicating a generally unbiased median response spectrum for the simulated records in comparison to the empirical results.

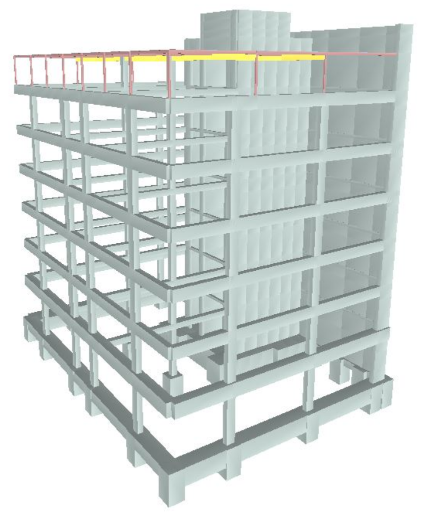

Figure 2: Seven-story building considered.

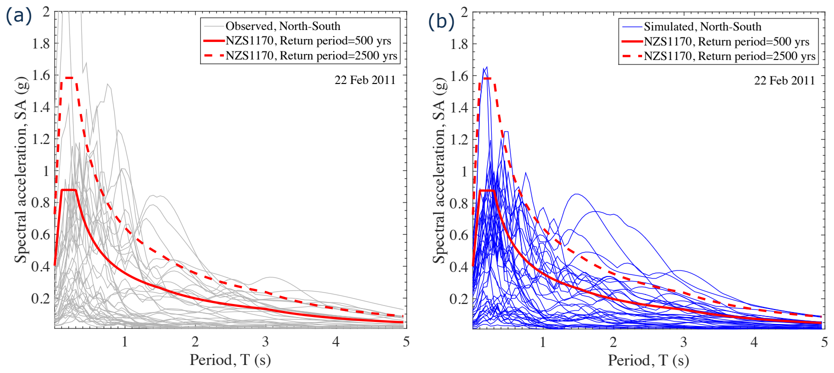

Figure 3: Response spectra of : (a) observed, and (b) simulated ground motions.

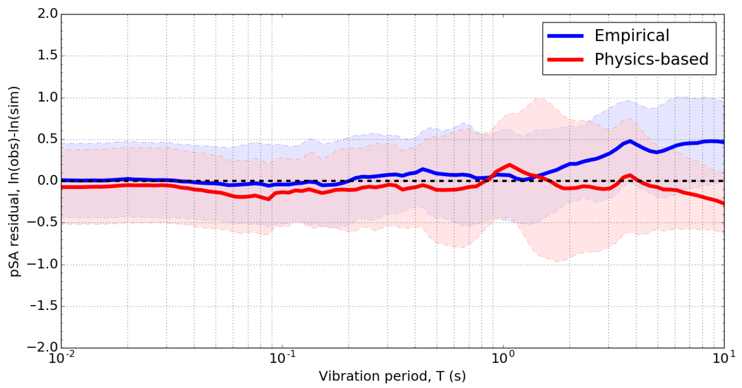

Figure 4: Spectral acceleration ratio of observed to simulated ground motions (Razafindrakoto et al. 2017).

4. Simulated and observed seismic response

Considering the general consistency in the spectral acceleration of the simulated and observed ground motions shown in Figure 4, the aim here is to investigate whether additional insights into the nature of the simulations can be obtained by examining seismic demand of engineered systems.

Figure 5 presents the center of mass acceleration and displacement of the roof of the building versus spectral acceleration at the fundamental translational period in the North-South direction.

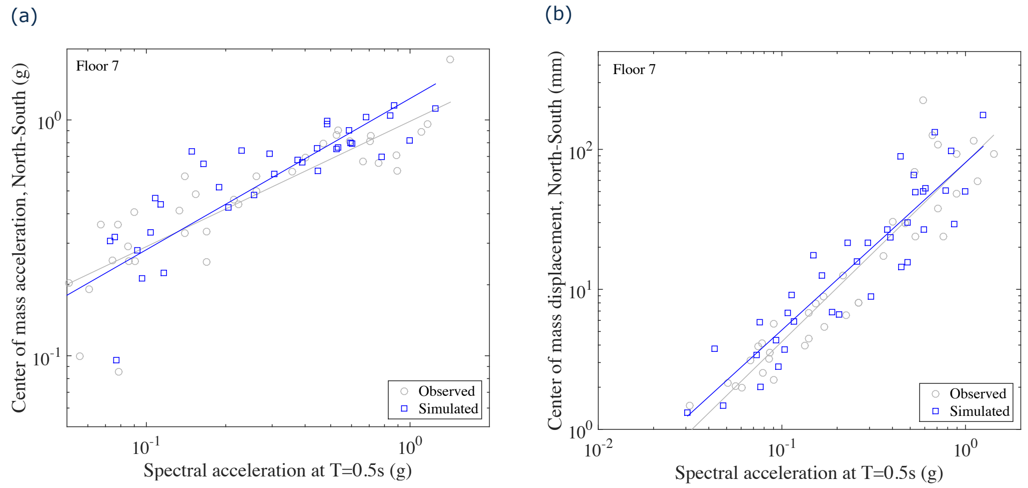

Figure 5: (a) Acceleration, and (b) displacement of the center of mass versus spectral acceleration at the fundamental translational period of the building.

Figure 6 presents the center of mass acceleration and drift of the roof from both simulated and observed ground motions. This figure shows that there is a general agreement between the responses from both ensembles, with over estimations from simulated ground motions (as most data points are above 1-1 line).

Figure 7 presents the ratio of the building response for the acceleration and drift profiles in the center of mass of floors.

As pointed out in Figure 6, there is an overestimations from the simulation ground motions, however, comparing the difference in the median ratio profile versus 1-1 line in Figure 7 (considering the variability in the response ratio) indicates that this over estimation is not significantly large.

Figure 7 also shows a large variation in the response ratio for the drift profile in comparison to acceleration.

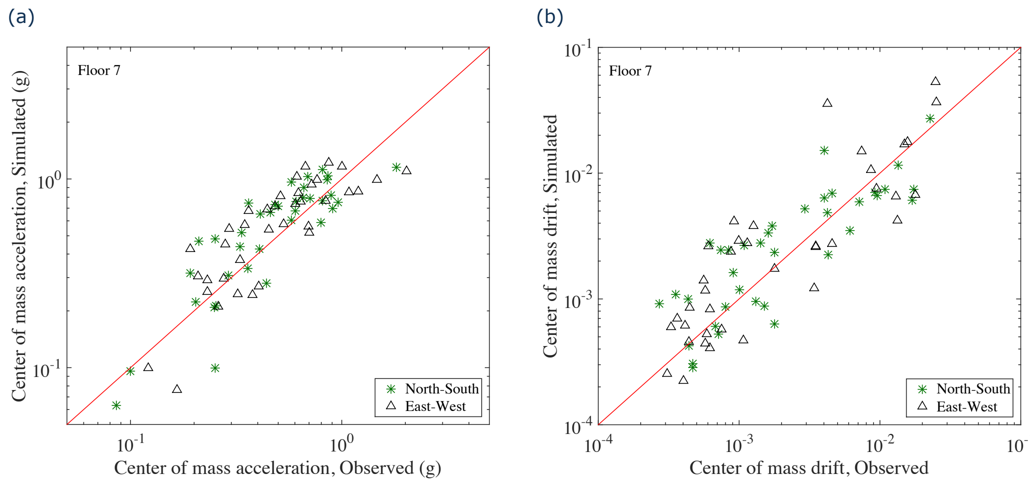

Figure 6: Comparison between seismic responses of the building from simulated and observed ground motions: (a) acceleration, and (b) drift of the center of mass.

5. Future work

Other buildings and geotechnical systems will be considered for further analyses to examine differences in the distribution of engineering demand parameters from simulated and observed ground motion ensembles representing various scenario ruptures. This will provide bases for improving various components of the ground motion simulation process (e.g., uncertainty treatment in source process and velocity model, nonlinear site response. etc.).

Both observed and simulated ground motions will be scaled to the design spectrum and the resulting demands from these ensembles will be examined.

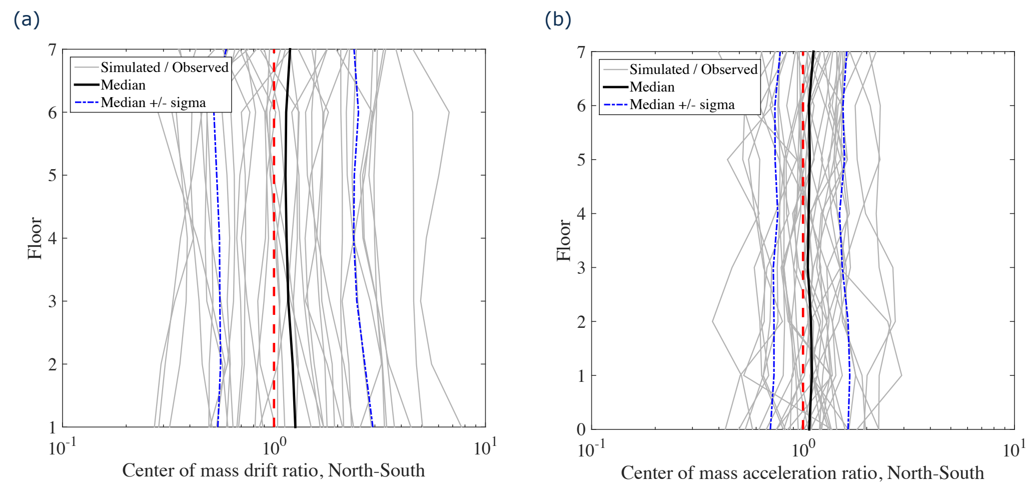

Figure 7: Seismic demand ratio of the building from simulated and observed ground motions: (a) acceleration, and (b) drift of the center of mass.