Final Project Summary — PEER Lifelines Program

Project Title—**ID Number**	*Calibration Sites for Validation of Non-Linear Geotechnical Models*—**2G01**		
Start/End Dates	5/1/00 – 9/30/03	Budget/ Funding Source	$81,952 / Caltrans
Project Leader (boldface) and Other Team Members	**Stewart (UCLA)**, M. Bora Baturay (UCLA), Annie O. Kwok (UCLA)		

1. Project goals and objectives

The objective of this project was to investigate the degree to which 1D ground response modeling can improve predictions of response spectral acceleration (S_a) relative to the use of attenuation relations. The potential "improvement" takes two forms: (1) removal of bias that might otherwise be present for a particular site condition, and (2) reduction of standard deviation. In two separate studies, those improvements were investigated first for the case of site-specific ground response analysis, and second for the use of site factors derived from 1D analyses by Silva and co-workers.

2. Benefits of the results of this project to develop technologies and protocols to mitigate the vulnerability of electric systems and other lifelines to damage directly and indirectly caused by earthquakes. Also, benefits to develop assessment techniques to evaluate damage to electric systems caused by earthquakes and to assess fiscal impacts due to the loss of electric service to the community.

The results of this project give Earthquake Engineers the opportunity to improve their predictions of ground motion intensity measures (IMs). The effect on IMs, and hence on electrical subsystem and lifelines, is greatest for soft clay sites, where predicted ground motions for rare events (e.g., 10% probability of exceedance in 50 years) would be reduced as a result of smaller standard deviations on IM when site-specific analyses are performed.

3. Brief description of the accomplishments of the project

The benefits of 1D site-specific analysis was evaluated by comparing S_a from recordings to predictions derived using ground response analysis procedures as well as attenuation relationships with and without amplification factors. The results were compiled for 134 motions from 68 sites, and prediction residuals are interpreted to assess the models' relative bias and dispersion. We found that ground response analyses are unbiased for $T \leq$ 1 s, but underestimate longer period S_a in deep basins. For soft soils (e.g., Holocene lacustrine-marine geology = Hlm), ground response analyses produce relatively low dispersion for $T < 1$ s relative to other site categories, as shown in Figure 1. This dispersion reduction is not observed for other models such as site factors or attenuation relationships. These results indicate that ground response analyses are beneficial for S_a predictions at soft soil sites, but generally provide no identifiable benefit for stiff soil or rock site conditions.

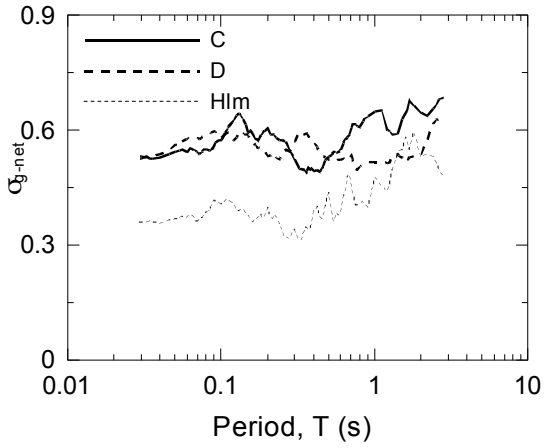

Fig. 1. Standard deviation term for use with results of 1D site specific ground response analyses

The calibration work for the Silva site factors model found that this model consistently under-predicted short-period spectral accelerations and over-predicted long period spectral accelerations. This is illustrated in Figure 2 by the positive residuals at short periods and the negative residuals at long periods. Based on these findings, it is recommended that empirical site factors, when available, generally be used in lieu of theoretical site factors.

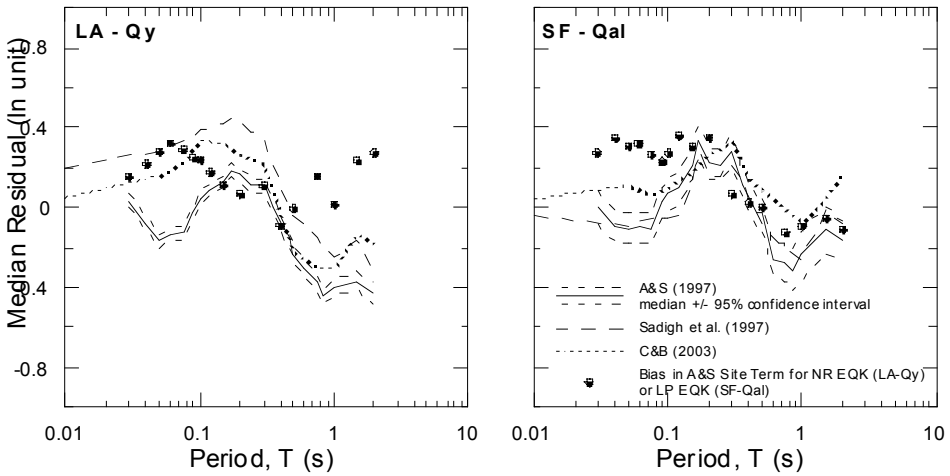

Fig. 2. Median and standard deviation of residuals of Silva 1D site factors model when applied with various attenuation models. Results shown for Quaternary alluvium site categories

4. Describe any instances where you are aware that your results have been used in industry

Results of the project on 1D site specific analysis were distributed among Caltrans design engineers by Cliff Roblee in an internal memo. Those results, along with the results on 1D amplification factors, have been the subject of discussions at NGA meetings.

5. Methodology employed

This evaluation of benefits of 1D site-specific analyses was performed by comparing S_a from recordings to predictions derived using ground response analysis procedures as well as attenuation relationships with and without amplification factors.

The validation of the 1D site factors was carried out by comparing response spectral accelerations predicted by the model to those recorded during earthquakes in the respective regions. The model predictions are prepared using a procedure that mimics how the model would be applied in engineering practice: ground motion estimates for a reference (rock) site condition are generated using three well-known empirical attenuation relationships, and the rock spectra are modified using the theoretical site factors.

6. Other related work conducted within and/or outside PEER

PEER Core program work developed empirical site factors used in the present studies.

7. Recommendations for the future work: what do you think should be done next?

PEER Lifelines Project 2G02 will investigate the use of nonlinear ground response procedures for estimation of site effects.

8. <u>Author(s), Title, and Date</u> for the final report for this project

Stewart, J. P. and Baturay, M.B. (2003). "Uncertainty and bias in ground motion estimates from ground response analyses," *Rpt. No. PEER-2003/02*, Pacific Earthquake Engineering Research Center, Univ. of California, Berkeley, June.

Stewart, J.P. and Kwok, A.O. (2004). "Application of theoretical 1D amplification factors for evaluation of seismic site effects," Report to Pacific Earthquake Engineering Research Center.