Final Project Summary — PEER Lifelines Program

Project Title—**ID Number**	*Benchmarking of Nonlinear Geotechnical Ground Response Analysis Procedures*—**2G02**		
Start/End Dates	7/1/04 – 6/30/06	Budget/ Funding Source	$253,317 / Caltrans
Project Leader (boldface) and Other Team Members	**Stewart (UCLA)**		

1. Project goals and objectives

This project consists of a benchmarking study of nonlinear ground response analysis procedures. The project has two principal objectives:

1. Identify the conditions for which nonlinear geotechnical modeling should be performed in lieu of more approximate equivalent-linear modeling.
2. Provide clear guidelines for the use of several nonlinear geotechnical models, with particular emphasis on the selection of input parameters. By following the guidelines for input parameter selection, users of the nonlinear codes should be able to obtain stable and unbiased median estimates of site amplification as well as reasonable levels of variability when model parameters and input motions are simultaneously varied over their distributions.

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 will 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 expected to be 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 nonlinear geotechnical analyses are performed.

3. Brief description of the accomplishments of the project

None to report – project was approved only recently, and project funds are not yet in place.

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

Not applicable.

5. Methodology employed

The project involves a broad array of researchers and practitioners working collaboratively. These individuals are divided into three groups. One group consists of the Management team (PI Stewart, graduate student Annie Kwok, Tom Shantz, and Yousef Bozorgnia). The second group is referred to as the "developers," and consists of researchers that have developed nonlinear ground response analysis codes. The third group is referred to as the "advisory panel," and consists of engineers and researchers who have significant experience with ground response analyses. By engaging the advisory panel throughout the duration of the project, we hope to solicit recommendations to help guide the project to ensure that it will produce useful results.

The developers and advisory panel members are listed below.

Code	Developer	Advisory Panel
DEEPSOIL	Hashash, Y	Chang, Susan
D-MOD_2	Matasovic, N.	Idriss, I.M.
TESS	Pyke, R.	Kramer, Steven
SUMDES	Wang, Z.L.	Makdisi, Faiz
OPENSEES	Yang, Z.	Martin, Geoff
		Mehia, Lelio
		Silva, Walter
		Sun, Joseph

A meeting of all participants is scheduled for September 21, 2004. At this meeting, the project team will finalize project objectives and scope. This scope is tentatively envisioned to include a sequence of benchmarking efforts. This sequence of tasks is conceived at present to include the following (modifications are possible based on feedback from developers and advisory panel members):

1. Model parameter selection protocols: Identify all parameters used in each nonlinear constitutive model that is being considered in the study. All model parameters should be identified as "fixed" or "free" parameters. Identify the values to be used for fixed parameters. For free parameters, use existing laboratory test data to develop 'baskets,' or rule-based procedures, for the selection of best estimate values and distributions of the parameters for various generic soil types (i.e., unsaturated clean sands and fines-dominated soils with various plasticities).
2. Model verification – very small strain (visco-elastic) conditions: Verify the accuracy of the wave propagation component of the models by solving problems involving fixed soil parameters and simple site layering.
3. Model verification – small to moderate strain conditions: Verify the nonlinear analyses using ground motions recorded in vertical arrays without liquefaction. The strains spanned by this data set are expected to vary from small to moderate.
4. Model verification – large strain conditions: Verify the nonlinear analyses using available centrifuge test data.
5. Parametric uncertainty studies – various strain ranges:
    a. For vertical array sites, randomize the appropriate parameters of the nonlinear soil models to represent appropriate (and pre-selected) ranges of shear wave velocity (V_s) profiles, modulus reduction curves (G/G_{max}), and soil damping curves (β). Input motions will consist of recorded downhole motions (producing small to moderate strains) and synthetic waveforms (producing large strains). Evaluate the parametric variability of the results to identify the input parameters to which the results are most sensitive.
    b. For vertical array sites, fix the parameters of the nonlinear soil model that control V_s, G/G_{max}, and β, and select an appropriate range for other model parameters, such as a viscous damping term. The parametric variability of the results will be evaluated.
6. Parametric studies involving selected codes: Perform analyses targeted at identifying the benefits of nonlinear ground response analyses relative to equivalent linear.

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

Many supporting studies have been performed in which the nonlinear codes were developed. Preliminary benchmarking studies have been performed in PEER Lifelines.

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

Not applicable.

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

Not applicable.