Opinion Paper on Uncertainties in Nonlinear Soil Properties

by

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This opinion paper is intended to respond to the third bullet listed under the stated objectives of the Workshop, namely, a discussion of the current status of site-response modeling and the quantification of uncertainties. I generally have been involved with seismic evaluations and designs of critical facilities for a number of agencies, both federal and local, for a number of years, and have noted the changes in our engineering approaches to these problems. During this period, the changes have been primarily led by the vast improvement in analysis capability, which has improved to such an extent that intuitively more realistic and complete approaches to analysis can be taken as compared to the very simplified methods previously available. At the same time, as these new approaches are developed, the previous conservatisms introduced due to the known restricted capabilities in analysis capability have been gradually removed from the analyses. As analytic capabilities have improved, the importance of quantifying uncertainties in soil properties and how to incorporate these into site response and soil-structure interaction evaluations have grown in importance.

Typical approaches to site response currently used to meet DOE/NRC guidelines make use of equivalent-linear probabilistic analyses with seismic hazard defined by rock outcrop spectra including definition of characteristic events. For these various characteristic events, site response analyses are usually performed to try to obtain mean estimates (based on many convolution analyses) of site amplification factors and surface ground motions along with corresponding definitions of strain iterated soil properties. The structural response analyses then make use of these results to evaluate soil-structure interaction effects and lead to seismic member loads for incorporation into design.

To perform these evaluations, the modeler must first evaluate the appropriate parameters needed for input to site response calculations. These include: low strain shear wave velocities, shear modulus reduction and hysteretic damping ratio strain-dependent functions, as well as additional associated site properties (grain size definitions, unit weights, water content, etc.). Issues such as liquefaction potential, soft zone collapse potential, seismic-induced settlement analyses, etc. make the required data set even more extensive and can be discussed in a similar fashion, but will not be addressed herein.

The parameters of primary interest to the site response modeler begin with the definition of the best estimate low strain shear wave velocity and damping profiles together with their potential uncertainty (± one sigma values) throughout the site profile. Estimates of these values are typically obtained from review of available field data (down-hole, cross-hole, SASW, etc.) as well as estimates of these values found from resonant column/torsional shear laboratory data. In current site response evaluations, information on variability of these strain-dependent functions from the mean values are typically used but often not provided. It has been my experience that these uncertainty functions are of secondary importance, provided that realistic estimates of the mean values are provided. Corresponding information on P-wave data is typically not discussed.

Unfortunately, I have found discrepancies or inconsistencies in some laboratory data that I think had not been evaluated in any consistent fashion during the laboratory test program. The laboratory results are often simply converted to modulus reduction and damping strain-dependent properties and presented for use as input to the analyses. Careful review of these data sometimes leaves the modeler with serious questions or concerns on the appropriateness of these data for input to site response evaluation. With fewer and fewer laboratories currently available for producing such data, fewer and fewer qualified laboratory technicians available and fewer and fewer projects requiring such data (as compared to previous periods), it is not always obvious that the data being recommended for use is appropriate. The serious analyst then is left with the unenviable task of making these evaluations, by comparing the results to available generic data and/or trying to evaluate the details of the test program and adequacy of the recommended laboratory test data. It is not unusual in these designs that bounding assumptions are then made, leading to potentially unnecessarily conservative evaluations and designs. It is probable that the modeler shouldn't be making these evaluations but should be relying on careful reviews by the experimentalists and his peer reviewers.

The questions typically asked by modelers with respect to the available data provided include the following. This list is also not complete. I realize of course that in some cases the questions are unanswerable, but it would help to a great extent if the experimentalists address these questions first, or together with the modelers, rather than the modelers alone.

- Have the data been obtained from a biased set of samples (only the best selected for testing)? Is disturbance (in sampling, handling and test preparation) felt to be significant?
- Are the low strain shear wave velocities consistent with the field geophysical data? If not, how should they be incorporated into selection of uncertainty in this data?
- Is measured low strain hysteretic damping consistent with current estimates from other test programs?
- How was the appropriate cycle selected from the available cyclic data? Did the test shake down to be consistent with the assumptions inherent in steady state assumptions?
- What are appropriate mean strain-dependent functions together with appropriate uncertainty bounds for shear modulus reduction and damping ratio? How do they compare with comparable information in the generic database?
- If the measured strain dependent functions are limited in upper bound strain, how should they be extrapolated for use in site response calculations?
- If the laboratory program is limited in scope, what are appropriate functions that should be used for the entire profile and what are the bases for these extrapolations?
- Was there anything strange or unusual noted in the program?
- Has the program been Peer Reviewed????