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Opinion Paper

Assessing Uncertainty in Dynamic Soil Properties

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On the forefront of current design techniques is use of reliability methods in civil engineering. Reliability-based design includes an estimate of uncertainty associated with variable design parameters. The final product of a reliability-based design process is not only the design value, but also some quantification of uncertainty associated with that value based upon all contributing factors. This type of design is becoming more popular in all fields of engineering as the cost of engineering failure continues to rise. It is especially desirable in geotechnical engineering where conservative design and the factor of safety are still commonly used to account for uncertainty. Little emphasis has been placed on determining uncertainty in dynamic soil properties to provide results useful in reliability-based design.

Uncertainty in soil properties consists of data scatter and systematic error. Data scatter is comprised of spatial variation and measurement uncertainty. Spatial variability is the quantification of the potential for a soil property to vary over a site. Measurement uncertainty is random variability of a repeated measurement on the same sample. Random measurement error attributed to the testing method must be separated from data scatter to assess real spatial variation.

Tuomi and Hiltunen (1996, 1997, and 1998) and Griffin and Hiltunen (2000) have empirically investigated measurement uncertainty associated with SASW and crosshole testing techniques. The methods employed in these studies were prohibitive to routine testing but gave credence to pursuing uncertainty assessment as a part of typical testing practice. Further research was completed (Marosi and Hiltunen [2001, 2003, and 2004]) to develop a practical means of incorporating measurement uncertainty quantification into the testing techniques.

Reliability-based design processes require quantification of uncertainty in material properties due to real spatial variation of the property over the design system. Soils are not homogeneous and this variability must be characterized. Analytical studies on soil liquefaction and earthquake ground motion predictions for example clearly demonstrate dependency of the calculations on spatial heterogeneity in material properties (Popescu, Prevost, and Deodatis [1997]).

There are two basic approaches to analytically account for spatial variability: 1) deterministic formulations that model the entire volume under consideration, and 2) stochastic models that account for spatial variability statistically. Deterministic models are often computationally impractical and expensive, and it is nearly impossible to provide true, accurate soil properties for each element in the model. Typically more practical, stochastic formulations model spatial variability via geostatistical correlation functions for each material parameter.

Spatial correlation structure has been documented in the literature for many soil parameters, e.g., index, strength, SPT N-value, and CPT tip resistance. There are little to no documented studies of the spatial correlation structure of dynamic soil properties, shear wave velocity for example, yet these properties are critical inputs for many geotechnical engineering problems. The position of the author is that a concentrated research effort should be made in this area. Techniques must be developed for assessing the spatial correlation structure of dynamic soil properties, including shear wave velocity and damping. These functions can then be used to more formally account for soil property uncertainty in analysis and design computations.

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