OPINION PAPER

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Uncertainty in ground response evaluations at a soil site is a function of uncertainty with regard to (a) the material properties of the soil within the profile and (b) the estimation of the rock input motion as shown in Fig. 1. Although the uncertainty associated with the rock input motion is often accounted for by using a suite of potential acceleration time histories; the uncertainty associated with the soil properties, such as shear modulus degradation and damping, are seldom adequately accounted for in analysis. This is the result of at least two factors. First, relationships defining shear modulus degradation and damping ratio as a function of cyclic shear strain have generally been defined by average values without specification of variation. Secondly, analyses which consider uncertainties in both soil properties and rock input motions, using programs such as SHAKE, require a large number of runs to obtain an understanding of the sensitivity of the ground response to various factors. As a result, analyses of this type become relatively time consuming and expensive to perform.

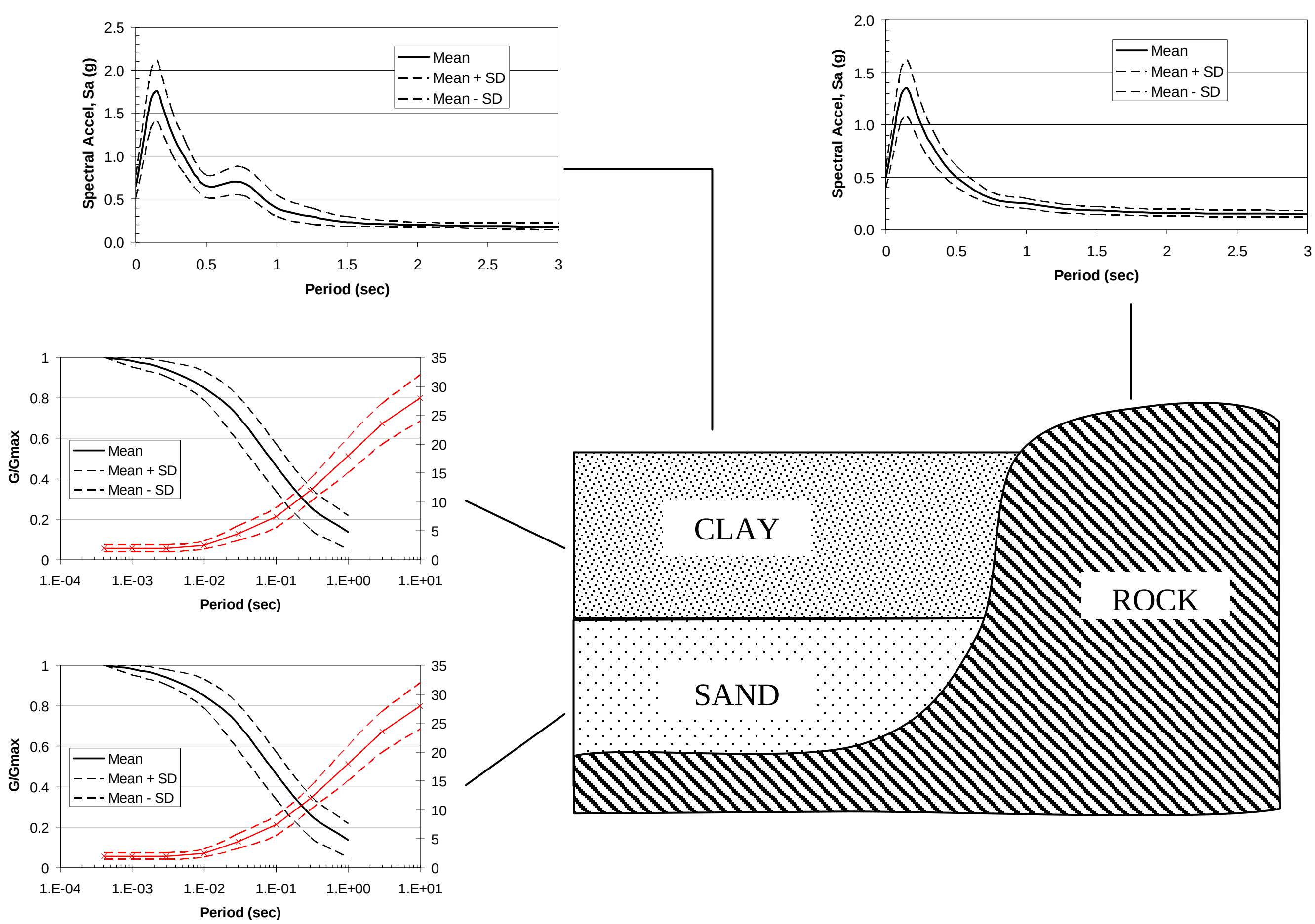

Fig. 1 Uncertainty in the rock input motion and in the dynamic properties of the soil leads to uncertainty in the estimate of ground response at a soil site.

Ideally, I would like to see a program similar to SHAKE which could easily account for uncertainty in rock input motion and soil parameters and produce a mean response spectrum with standard deviation bounds as illustrated in Fig. 1. I understand that efforts in this direction are presently underway at Caltrans and this would represent a significant advance for our profession.

An example of the significance of rock input motions to the computed ground response is provided by analyses performed for Treasure Island following the Loma Prieta earthquake. Reasonably good agreement was obtained between the computed and measured response spectrum using a measured rock motion (Yerba Buena Is.) close to the site. However, if alternate measured rock input motions at similar distances were used, there was considerable variation in computed spectra. Fig. 2 presents the mean and mean ± one standard deviation spectra computed at Treasure Island using seven measured rock input motions. For this suite of rock input records, it would be necessary to use the mean plus one standard deviation boundary to envelope the measured spectrum at Treasure Island.

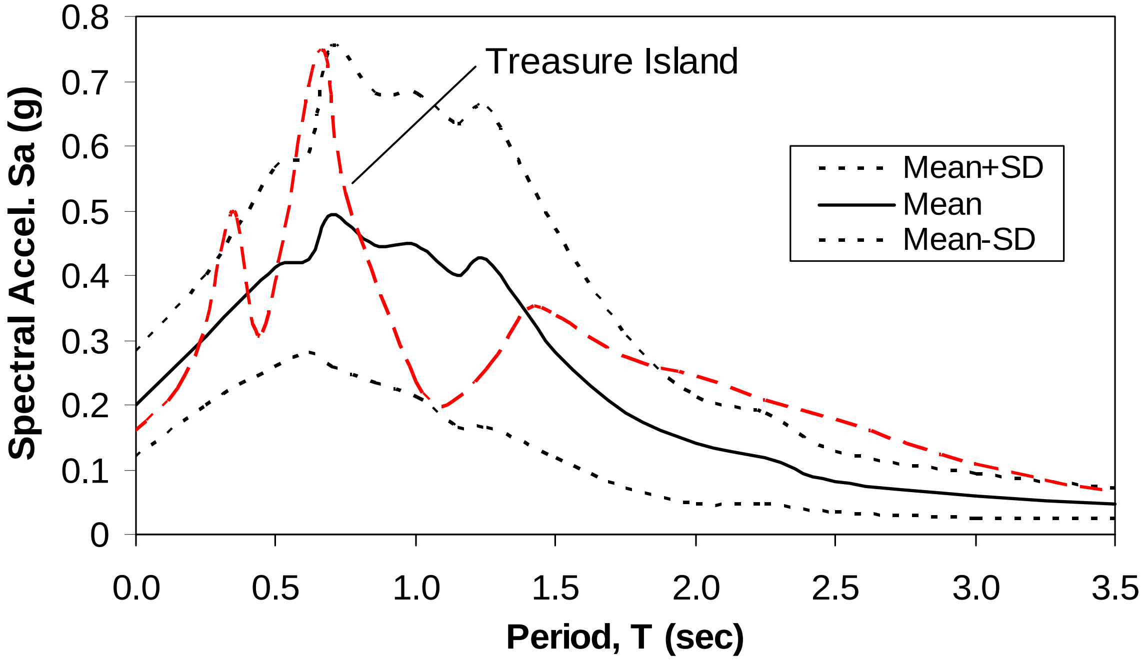

Fig. 2 Comparison of measured response spectrum for Treasure Island in comparison with mean and mean ± one standard deviation response spectra computed using seven Loma Prieta rock input motions.

In engineering practice the appropriate G/G_{max} vs. shear strain curve is often selected based on the plasticity index for the soil using relationships developed by Vucetic and Dobry (1988) or Sun et al (1988). In fact, each of these curves represents the average relationship obtained from a number of laboratory tests on soils having plasticity indices within a given range. For example, Fig. 3 shows the measured G/G_{max} vs. shear strain curves for PIs between 40 and 80 compiled by Sun et al. Obviously, there is considerable variation about the mean curve for this grouping of soils which could lead to variations in the modulus or shear wave velocity computed in a ground response analysis. As shown in Fig. 3, at 0.1% shear strain G/G_{max} could range from 0.4 to 0.8.

Even small changes in the shear modulus can produce important but potentially unexpected changes in the computed ground response.

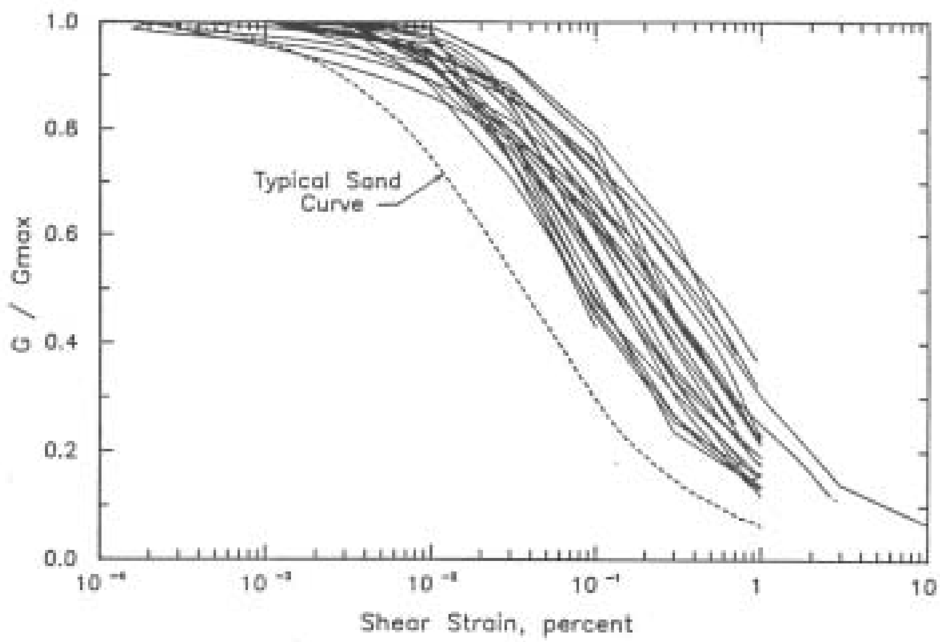

Fig. 3 Normalized modulus reduction relationships for clays with PIs between 40 and 80. (Sun et al, 1988).

In addition, to the uncertainties already discussed, there are a number of other instances where additional laboratory or field testing is needed to provide insight into expected ground response. For example, in many regions of the country where there sediments (Los Angeles, Salt Lake City, Central US) overly rock, engineers and seismologist are interested in the behavior of soils and partially consolidated sediments which might be subjected to significant confining pressures. In many cases, analyses have been performed which focus on the response of the upper 30 to 90 m of the soil profile and largely ignore the influence of the deeper sediments. Some studies suggest that this approach can lead to an underestimate of the long period response of the sediments which may be important for tall buildings and bridges. Even when velocity data is available for these materials, modulus degradation and damping values are often very uncertain. Additional study of the behavior of geo-materials under large confining pressures is warranted.

Lastly, collapsible soils (alluvial and aeolian) are located in many seismically active areas around the world. When these materials are encountered, current US code provisions require a site-specific ground response analysis. Unfortunately, engineers who must then perform these analyses have very little test data upon which they can base their analyses. Although one would expect site specific testing to be performed for these materials, this is often not economically feasible except for major projects and engineers are left to use their own judgment. Post-earthquake investigations have shown that these materials can produce spectacular landslides if the meta-stable structure is destroyed by induced shear stresses. Determination of the shear modulus and damping relationships for these soils would be very desirable.