Effects of Geology on Nonlinear Soil Properties

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DESCRIPTION

This paper presents some results of a recent study to develop procedures and guidelines for estimating the nonlinear properties of South Carolina soils (Andrus et al. 2003; Zhang 2004). The procedures are developed using existing laboratory measurements of normalized shear modulus and material damping ratio made by eight different laboratories.

DATA SET

The data set includes mainly Resonant Column and Torsional Shear test results for 122 specimens taken from South Carolina and surrounding states. Of the 122 samples, 78 are from three general areas in South Carolina: Charleston, Savannah River Site (SRS), and Richard B. Russell Dam (RBRD). The other 44 samples are from North Carolina and Alabama.

The Charleston and SRS areas lie in the Coastal Plain physiographic province, where surficial deposits range from soft Quaternary sediments to relatively stiff Tertiary and Cretaceous sediments. The RBRD area and the North Carolina and Alabama sampling areas lie in the Piedmont physiographic province, which consists largely of shallow zones of residual and saprolites soils overlying rock. Residual soils are clay-rich earths that are the remains of completely weathered rock. Saprolites are highly decomposed rock without the clay accumulation. Grouping the test data by general geology appears to account for some of the scatter observed in the data set.

The test samples were collected from depths ranging from 0.6 m to 326 m, with about 72 % from depths less than 30 m. Most samples were tested at confining stress levels similar to the estimated field mean effective stress (s'_m). Some were tested at several different confining stress levels to reflect the stress ranges soils at the site were expected to experience.

RESULTS

Based on a statistical analysis of the data set (Zhang 2004), design curves of normalized shear modulus (G/G_{max}) and material damping ratio (D) are developed. A modified hyperbolic model (Stokoe et al. 1999) and the following variables define the G/G_{max} design curves: strain amplitude, confining stress, plasticity index (PI), and geology and age. G/G_{max} design curves for four general soils at s'_m = 100 kPa are presented in Figure 1. The four general soils are: 1) Holocene-age (< 10,000 years) sand with PI = 0, 2) Pleistocene-age (10,000 to 1.8 million years) sand with PI = 0, 3) Tertiary-age (1.8 to 65 million years) sand with PI = 0, and 4) saprolite soil with PI = 0.

Also presented in Figure 1 are the mean and range curves proposed by Seed et al. (1986) for sand. As observed in the figure, the Holocene sand curve exhibits more linearity than the three curves for older sands, and generally follows the Seed et al. (1986) upper range curve for sand. It should be noted that the Holocene sand curve also generally follows the curves proposed by Idriss (1990) and Stokoe et al. (1999) for sands, not shown in the figure. The Pleistocene sand curve generally follows the Seed et al. (1986) lower range curve for sand, whereas the Tertiary sand and saprolite soil curves generally follow the Seed et al. (1986) mean curve for sand, as well as the Vucetic and Dobry (1991) $PI = 0$ curve, not shown in the figure.

The D design curves are expressed in terms of a minimum damping ratio (D_{min}) and a function of G/G_{max}, which is based on regression analysis of G/G_{max} and D-D_{min} data. Relationships between D_{min} and PI are developed for various geologic units using the Torsional Shear test data only. The D design curves model the complex relationship between PI and D that has been observed by other researchers (e.g., Pyke 1993, Vucetic et al. 1998, Stokoe et al. 1999, Darendeli 2001). The curve for Holocene sand with PI = 0 plots close to the Seed et al. (1986) lower range curve for sand and the Idriss (1990) curve for sand and clay. The D curves for older sands generally plot between the Seed et al. (1986) mean and lower range curves for sand.

SIGNIFICANCE

In addition to confining stress and PI, geology appears to account for some of the other factors influencing G/G_{max} and D relationships, such as higher in situ G_{max} (or small-strain shear wave velocity) values observed in older soil deposits. The effects of geology may also explain some of the differences between G/G_{max} and D curves developed by various researches. These differences may have significant impact on modeling dynamics soil response.

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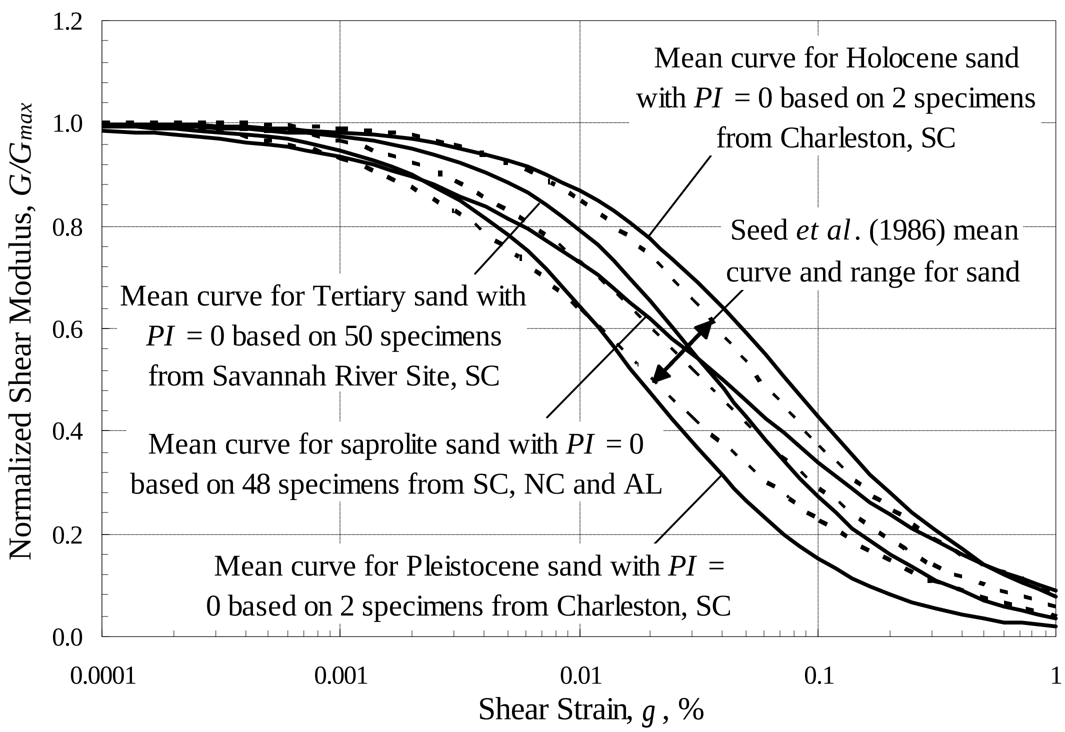

Figure 1. Comparison of G/G_{max} curves developed by Zhang (2004) for various $PI = 0$ South Carolina soils at s'_m = 100 kPa with Seed *et al*. (1986) mean and range curves for sand.