EFFECTS OF THE CYCLIC LOADING FREQUENCY AND RATE OF SHEARING ON THE INPUT SOIL PARAMETERS FOR SEISMIC SITE RESPONSE ANALYSES

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One of the methods for the reduction of earthquake damages in populated areas is the analysis of the response of local soil deposits to earthquake loads, commonly called the seismic site response analysis. Its purpose is to evaluate the behavior of soil formation at a specific location of an existing or planned structure during anticipated earthquake. The elementary component of cyclic soil behavior due to seismic load is the cyclic stress-strain loop. Consequently, the computer models for the seismic site response analyses include the properties of cyclic loops and their variation with the level of cyclic shear strain amplitude, γ_c, and the number of cycles, N. The modulus reduction curve, G_{s1}/G_{max} versus log γ_{c1}, and damping curve, λ_1 versus log γ_{c1}, are the most frequently used curves describing the variation of the slope and size of the initial cyclic loop with γ_c. Here, $G_{s1}=\tau_{c1}/\gamma_{c1}$= secant shear modulus of the initial stress-strain loop (slope of the loop), where γ_{c1} and τ_{c1} are the cyclic shear strain and stress amplitudes in the first cycle, G_{max}=maximum shear modulus at γ_c approaching zero, and $\lambda_1=\Delta W_1/(2\pi\gamma_{c1}\tau_{c1})$= initial equivalent viscous damping ratio, where ΔW_1= the area of the first fully closed cyclic loop. Besides γ_{c1} and N, the properties G_{s1}, G_{max} and ΔW_1 depend on many other factors, such as the soil type, confining stress, geologic history, frequency of cycling and the rate of loading or straining in any given cycle. Among these factors, it seems that the effects of the frequency and rate of shear straining have not been fully recognized and adequately taken into account in earthquake engineering practice, although these effects can profoundly affect the outcome of the seismic site response analysis.

In the lecture, the results of relatively recent studies on the effects of frequency and rate of shear straining on the shape of cyclic loop and the values of G_{s1}, G_{max} and ΔW_1 are described. Unique results obtained in the range of very small cyclic shear strain amplitudes, γ_c, which are essential for seismic site response analyses, are also included. Below are just two interesting charts from the presentation.

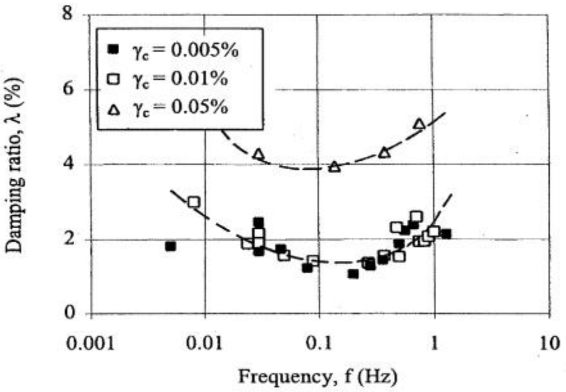

Figure 1. Variation of the equivalent viscous damping ratio, λ_1, with the frequency of cyclic shearing, f, for a high-plasticity clay having PI=44 (Lanzo et al., 1999)

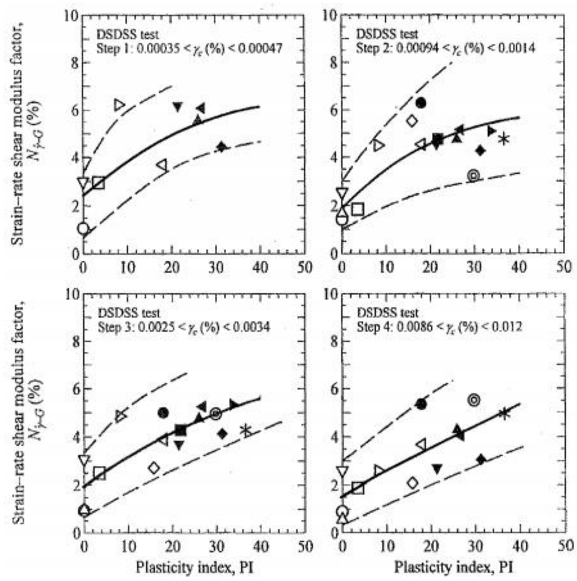

Figure 2. Trend of the strain-rate shear modulus factor, $N_{\dot{\gamma}\text{-G}}$, with the soil's plasticity index, PI, for the range of consolidation stresses σ'_{vc}= 50 – 650 kPa - factor $N_{\dot{\gamma}\text{-G}}$ describes the relative increse of G_{s1} with the average shear strain rate, $\dot{\gamma}$, in a single cycle of strainig (Tabata and Vucetic, 2004; Vucetic and Tabata, 2003)

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