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Effect of Material Properties on Soil Liquefaction

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SYNOPSIS Four material constants included in the pore-pressure buildup equation for saturated sands under earthquake loadings are determined as functions of grain size, soil angularity, coefficient of uniformity, and void ratio. This would allow engineers to readily calculate pore-pressure buildup as a function of time, and hence assess the liquefaction potential, for a given soil without conducting cyclic tests.

INTRODUCTION

The authors have previously proposed equations (summarized below) which predict pore-pressure buildup in saturated sands under earthquake-type loading (Sherif et al., 1978):

$$U_N^* = U_{N-1}^* + \frac{1}{2}\left(\Delta U_{Np}^* + \Delta U_{Nn}^*\right) \quad (1a)$$

$$\Delta U_{Np}^* = \left(1 - U_{N-1}^*\right) \cdot \frac{C_1 (N_{eq})_p}{(N_{eq})_p^{C_2} - C_3} \cdot \left(\frac{\tau_{Np}}{\bar{\sigma}_{N-1}}\right)^{\alpha} \quad (1b)$$

$$\Delta U_{Nn}^* = \left(1 - U_{N-1}^*\right) \cdot \frac{C_1 (N_{eq})_n}{(N_{eq})_n^{C_2} - C_3} \cdot \left(\frac{\tau_{Nn}}{\bar{\sigma}_{N-1}}\right)^{\alpha} \quad (1c)$$

$$(N_{eq})_p = \sum_{i=1}^{N} \left(\frac{\tau_{ip}}{\tau_{Np}}\right)^{\alpha}, \quad (N_{eq})_n = \sum_{i=1}^{N} \left(\frac{\tau_{in}}{\tau_{Nn}}\right)^{\alpha} \quad (1d)$$

where U_{N-1}^* and U_N^* are the normalized pore-pressure values at the end of the $N-1^{th}$ and N^{th} cycles, ΔU_{Np}^* and ΔU_{Nn}^* are the normalized pore-pressure increments due only to the maximum positive and negative shear stresses, τ_{Np} and τ_{Nn} respectively, during the N^{th} cycle. C_1, C_2, C_3, and α are the material constants which are determined during this study. The reader can refer to their previous paper (Sherif and Ishibashi, 1979) for the practical use of this equation.

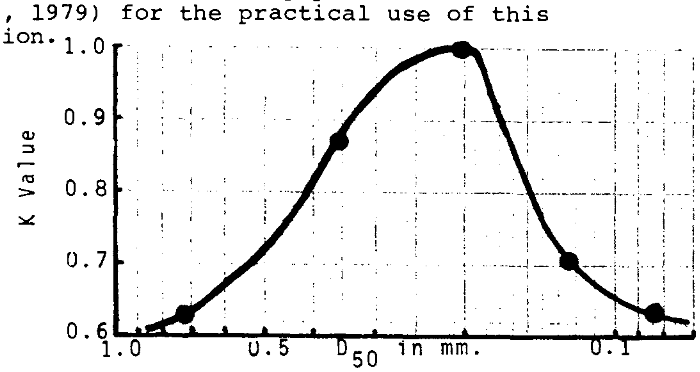

Fig.1 Constant K versus Mean Grain Size D_{50}

PARAMETERS C_1, C_2, C_3, AND α

These parameters were determined by running liquefaction tests in the Torsional Simple Shear Device for nine soil types with various mean grain size D_{50}, sphericity ψ, uniformity coefficient C_u, and volume decrease potential $e\text{-}e_{min}$. C_2 and C_3 appear to be constant for all soil types and densities and are nearly equal to 2.0 and 0.5, respectively. The α value can be expressed as a function of volume decrease potential for all soil types:

$$\alpha = 5.6\,(e-e_{min}) + 1 \quad (2)$$

and C_1 can be expressed as a function of ψ, C_u, D_{50}, and $e\text{-}e_{min}$ as:

$$C_1 = K \cdot \psi^{5.4} (e-e_{min})^{2.25} \frac{10.66}{C_u^2 - 2.07C_u + 1.1} + 74 \quad (3)$$

where K is the grain-size function as shown in Fig. 1 and is equal to unity at D_{50} = 0.2 mm. This implies that 0.2 mm is the most critical mean grain size for liquefaction. It is concluded that Eq. 1 can be readily used for liquefaction prediction after the basic soil properties, D_{50}, ψ, C_u, and $e\text{-}e_{min}$ are known. It should be recognized that soil angularity (or sphericity) and volume decrease potential are more important than relative density in evaluating soil liquefaction potential.

REFERENCES

Sherif, M.A., I. Ishibashi and C. Tsuchiya (1978), "Pore-Pressure Prediction During Earthquake Loadings," Soils and Foundations, Japanese Soc. of Soil Mech. and Found. Eng., Vol. 18, No. 4.

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