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Numerical Assessment on Shear Moduli at Pre-failure State Taken from Pressuremeter Test

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This paper investigated the deformational characteristics of sandy soils at pre-failure state by using the numerical simulation of pressuremeter tests. Numerical simulations of cavity expansion were performed with a pseudo-elastic soil model, which was developed based on the cross anisotropy concept and the Ramberg-Osgood model for anisotropy and nonlinearity of soil, respectively. Assumptions of the existing analytical solution on the deformation of sandy soils due to cavity expansion were examined. Model parameters were studied, which describe the nonlinearity and anisotropy of soil deformation. In addition, the effect of finite length of the pressuremeter was numerically estimated, as was the extent of influence of cavity expansion. The existing solution, based on the isotropic and linear elastic assumption, overestimates the tangential shear modulus in the nonlinear strain range. Meanwhile, the tangential modulus taken from the pressuremeter test relatively concurs with the secant modulus of soil. Consequently, the simulation results indicated that the parameters related to the horizontal direction have a dominant effect on the shear modulus.

INTRODUCTION

The pressuremeter test is known to be one of the most effective in situ tests used to evaluate soil deformation characteristics. While other in situ tests indirectly compute soil moduli by applying empirical correlations to the measured values, or compute only the elastic moduli for a very small strain range, the pressuremeter test directly measures the stress-strain data and uses this to determine the shear modulus of soil. Thus, soil nonlinearity can be estimated for a wide strain range. Further, the pressuremeter test has clearer boundary conditions than other in situ tests.

All types of soil show nonlinear and anisotropic deformation behavior as observed in numerous laboratory test results and in the data of field measurements (Tatsuoka and Shibuya, 1992; Burland, 1989). However, pressuremeter test results have been generally utilized for evaluating only one modulus value from a given pressure-expansion curve based on the assumption of isotropy and linear elasticity, even though a nonlinear pressure-expansion curve had previously been obtained. Due to a recently increasing interest in the nonlinearity of soils, various researchers have carried out studies on the nonlinear characteristics of soil using pressuremeter tests. For example, the idealized constant-volume cylindrical cavity expansion analysis has been used to study the nonlinear behavior of clay soils (Wood, 1990; Jardine, 1992). In addition, several closed-form solutions that were used to simulate the whole curve of the pressuremeter test were presented based on curve fitting methods (Sadeeq and Clarke, 1995; Bolton and Whittle, 1999). Fahey and Carter (1993) estimated the nonlinear behavior of sand using a nonlinear elastic model with Mohr-Coulomb failure criteria, in which the modified hyperbolic equation for simulating nonlinear behavior was used in an axisymmetric and a vertical plane strain condition. In addition, a comparative study was carried out on the relationship between unload-reload shear modulus, G_{ur}, and maximum shear modulus, $G_{\max}$, by using calibration chamber tests (Bellotti et al., 1989). However, in spite of these studies on the effect of soil nonlinearity, shear modulus evaluation from a pressuremeter test is still questionable because of the difficulty in simulating the anisotropic and nonlinear soil behavior, and because of the shortage of comparative studies between predictions and measurements.

This study is concerned with shear modulus evaluation from a pressuremeter test at pre-failure state for sandy soils. The numerical simulation was performed with the pseudo-elastic soil model developed for anisotropic and nonlinear behavior (Jung et al., 2005). The conventional method for evaluating the shear modulus from the pressuremeter test, based on the widely used isotropic linear elastic theory, was examined. In addition, the governing factors of soils for shear modulus were investigated, while the problems with influencing range and probe geometry were discussed.

DETERMINATION OF SHEAR MODULUS FROM PRESSUREMETER TEST RESULTS

Fig. 1 shows a schematic diagram of the pressuremeter test, where the conventional analytical approach for the pressuremeter test uses a number of simplifying assumptions to obtain a solution. First, because the probe is assumed to be vertical and infinitely long, all movements of the probe are in the radial direction under the plane strain condition in the axial direction. Second, the soil is assumed to be of an isotropic, linear elastic material.

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