III-172 SIMULATION OF PHASE TRANSFORMATION PHENOMENA OF SAND

KA-CHING SAN OSAKA UNIVERSITY

TAMOTSU MATSUI OSAKA UNIVERSITY

INTRODUCTION

This paper presents simulation of phase transformation phenomena of sand appeared in the undrained triaxial test with different values of void ratio and in the strain controlled triaxial drained test with different values of volume strain and axial strain ratio.

MODELING OF SAND

In the generalized plasticity theory (Pastor and Zienkiewicz, 1986), dilatancy d is approximated by a linear function of stress ratio η

$$d = (1+\alpha)(M_g - \eta) \qquad (1)$$

$$M_g = \frac{6 \sin\phi_g}{3 - \sin\phi_g \sin 3\theta} \qquad (2)$$

where α is a material constant, θ Lode's angle and ϕ_g a constant residual angle of friction.

The unit vector defining the direction of plastic flow is given by

$$(n_{gv}, n_{gs}) = \frac{1}{\sqrt{(1+d_g^2)}}(d_g, 1) \qquad (3)$$

The direction discriminating between loading and unloading is characterized in a similar manner:

$$(n_v, n_s) = \frac{1}{\sqrt{(1+d_f^2)}}(d_f, 1) \qquad (5)$$

and $d_f = (1+\alpha)(M_f - \eta)$ (6)

Usually, the value of M_f is approximated as the value of M_g multiplies by the relative density. In this paper, the void ratio is approximated by a hyperbolic function of M_f/M_g ratio,

$$e = \frac{M_f / M_g}{A + B(M_f / M_g)} \qquad (7)$$

where e is void ratio and A and B the material constants.

UNDRAINED TRIAXIAL TEST

Fig.1 shows the shear stress- axial strain curves and effective stress-paths for an initial effective confining pressure of 1 MPa with different values of void ratio obtained from undrained triaxial tests. When the void ratio of or less than 0.856, it can be observed that there is a state of the phase transformation where the response changes from contractive to dilative and that no softening appears. Fig.2 shows the simulation of the undrained triaxial tests with different values of M_f/M_g ratio. The agreement between the analytical results and the test results is very well. Fig.3 shows the relation between the void ratio and M_f/M_g. The agreement between the Eq.(7) and test results is excellent.

STRAIN-PATH CONTROLLED TRIAXIAL TEST

Phase transformation also appears in the strain-path controlled triaxial test (Uchida and Vaid, 1992). The strain-path controlled triaxial test is performed with a constant volume strain

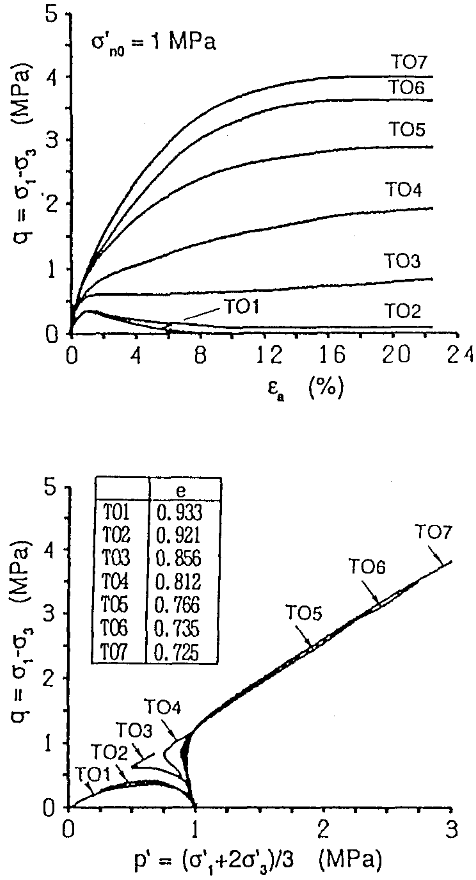

Fig.1 Undrained triaxial test results with different values of void ratio (after Verdugo and Ishihara, 1991)

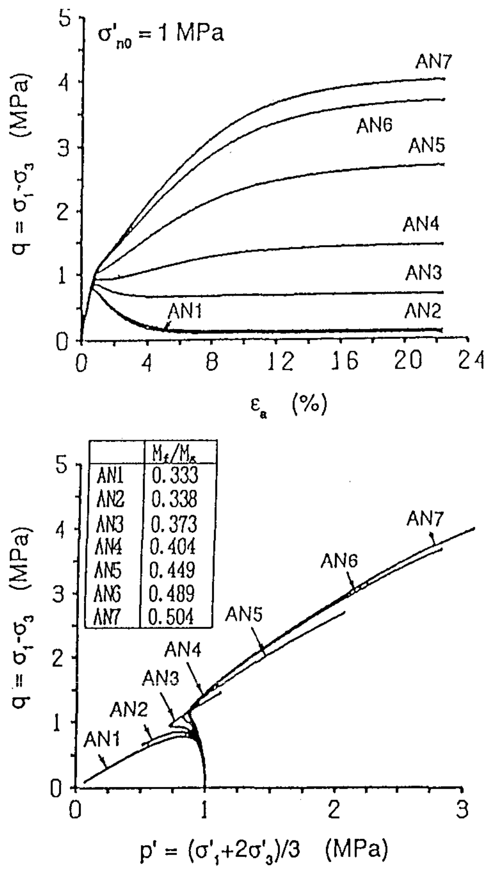

Fig.2 Simulation of the undrained triaxial test with different values of M_f/M_g ratio

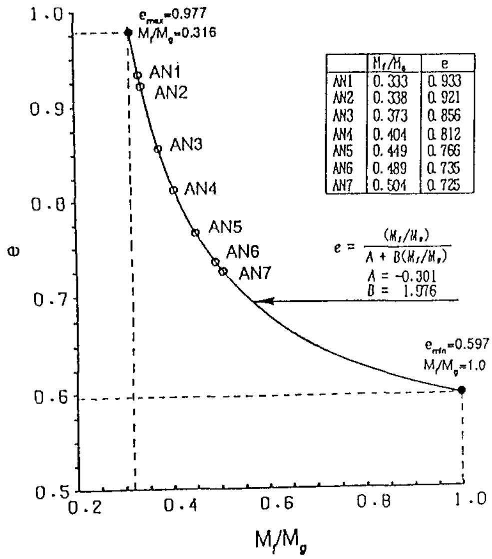

Fig.3 Relationship between void ratio and M_f/M_g ratio

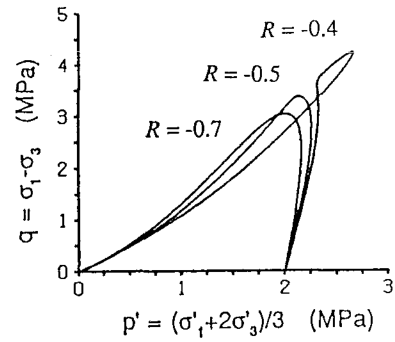

Fig.4 Simulation of strain-controlled triaxial test with different values of R

and axial strain increments ratio R,

$$R = \frac{d\varepsilon_v}{d\varepsilon_a} \quad (8)$$

where ε_v and ε_a are the volume and axial strains.

For a constant effective confining pressure and relative density, phase transformation was observed by varying R (Uchida and Vaid, 1992). It showed that the softening occurred before or after the stress path reached the failure line depending on the value of R.

Fig.4 shows the analytical stress-paths with different R. The trend of phase transformation appeared in the strain controlled test is successfully reproduced.

CONCLUSIONS

Simulation of the phase transformation phenomena of sand appeared in the undrained triaxial test with different values of void ratio and in the strain controlled triaxial drained test with different values of volume strain and axial strain ratio were performed successfully. The proposed hyperbolic function between the void ratio and M_f/M_g, such as Eq.(7), agreed the test data excellently.

REFERENCES

Pastor, M. and Zienkiewicz, O. C, "A generalized plasticity hierarchical model for sand under monotonic and cyclic loading", Proc. 2nd Conf. on Numerical Models in Geomechanics, Ghent, pp131-150 (1986).

Verdugo, R. and Ishihara, K, "Characterization of the undrained behavior of sandy soils", Proc. Int. Symposium on Natural Disaster Reduction and Civil Engineering, Osaka, JSCE, pp287-296 (1991).

Uchida, K. and Vaid, Y. P. " Strain-path controlled triaxial test" Proc. 27th National Conf. on SMFE, JSSMFE (1992). (in press) (in Japanese)