III－182

Analyses of drained and undrained cyclic behavior of clay

Nagoya Inst. of Tech. Student member ○ Chowdhury E. Q.
Nagoya Inst. of Tech. Student member Hoshikawa T.
Nagoya Inst. of Tech. Member Nakai T.

INTRODUCTION

A new version of kinematic t_{ij}-clay model (ver.4) was proposed[1)], which can describe the drained stress-strain behavior of clay under monotonic and cyclic loading with various stress histories. Validity of that model was also confirmed by the drained conventional triaxial cyclic tests. In the present paper that model is used to analyze the undrained cyclic behavior of clay. Analyses show a good agreement with the general observed trend.

BRIEF MODEL OUTLINE

Total strain increment is given by

$$d\varepsilon_{ij} = d\varepsilon_{ij}^{e} + d\varepsilon_{ij}^{p} = d\varepsilon_{ij}^{e} + d\varepsilon_{ij}^{p(FR)} \quad (1)$$

where, the elastic and plastic components are

$$d\varepsilon_{ij}^{e} = \frac{1+\nu_e}{E_e} d\left(\frac{\sigma_{ij}}{1+X^2}\right) - \frac{\nu_e}{E_e} d\left(\frac{\sigma_{kk}}{1+X^2}\right)\delta_{ij} \quad (2)$$

$$d\varepsilon_{ij}^{p} = \Lambda \frac{\partial g}{\partial t_{ij}} \quad (3)$$

Elastic modulus E_e is expressed in terms of the swelling index k and Poison's ratio ν_e as :

$$E_e = \frac{3(1-2\nu_e)(1+e_0)}{k} t_N \quad (4)$$

The yield function is given by as follows:

$$f = \ln t_N + \zeta(Z) + c = 0 \quad (5)$$

where

$$\left.\begin{aligned} \zeta(Z) &= \frac{-\alpha}{(1-\alpha)} \ln\left|1 - (1-\alpha)\frac{Z}{M^*}\right| \quad &(\alpha \neq 1) \\ &= \frac{Z}{M^*} \quad &(\alpha = 1) \end{aligned}\right\} \quad (6)$$

$$Z = X^* + n \quad (7)$$

$$X^* = \sqrt{(x_{ij} - n_{ij})(x_{ij} - n_{ij})} \quad (8)$$

$$n = \sqrt{n_{ij} n_{ij}} \quad (9)$$

Since it is well known that stress-dilatancy relation of clay is influenced by stress history, plastic potential function in the present model is given so as to account such characteristics as follows:

$$g = \ln t_N + \left(\frac{1}{G}\right)^{l} \zeta(Z) \quad (10)$$

Where, G corresponds to the reciprocal of over consolidation ratio (OCR) under isotropic stress condition and is given by equation (11).

$$G = \frac{t_{N1}}{t_{N1e}} \quad (0 < G \leq 1) \quad (11)$$

$$t_{N1} = t_N \exp\{\zeta(X)\} \quad (12)$$

$$t_{N1e} = t_{N0} \exp\left\{\frac{1+e_0}{\lambda - k} \varepsilon_{v(2)}^{p}\right\} \quad (13)$$

$\varepsilon_{v(2)}^{p}$ is the plastic volumetric strain produced by overconsolidation or previous shear loading. Finally referring to Hashiguchi's sub-loading surface model[3)] the proportionally constant of equation (3) is given by

$$\Lambda = \frac{\left(\dfrac{\partial f}{\partial \sigma_{ij}} d\sigma_{ij}\right) G^{l}}{\dfrac{1+e_0}{\lambda - k}\left\{\dfrac{\partial g}{\partial t_{kk}} - a\dfrac{\ln G}{t_N}\right\}} \quad (14)$$

Newly introduced parameter a and l are determined by trial to fit the stress-strain curve.

RESULTS AND DISCUSSION

Figure 1 shows the stress paths for the drained cyclic tests used to check the validity of the present model. Figures 2 and 3 show stress ratio (q/p) vs. axial strain (ε_a) and stress ratio (q/p) vs. volumetric strain (ε_v) respectively for the test paths shown in figure 1. From these figures we can conclude that present model analyses are in sufficient agreement with the test results.

Now, using this model analyses are performed to check the undrained response of clay under cyclic loading. Figure 4 shows the effective stress paths of the analyses with different amplitude of deviator stress and figure 5 shows the corresponding stress ratio (q/p) vs. axial strain (ε_a) relations. Undrained response observed in the analyses supports the general trends of undrained behavior of clay. Following are the parameters used in the analyses: $\lambda/(1+e_0) = 5.08\times10^{-2}$, $k/(1+e_0) = 1.12\times10^{-2}$ $\phi' = 33.7^\circ$, $\alpha = 0.7$, $\nu_e = 0.0$, $\xi = 0.2$, $a = 5$ and $l = 0.5$. Here the parameters except a and l are the same as those of previous model[2)].

REFERENCES

1) Nakai, Hoshikawa and Chowdhury (1995): Proc. *IS-TOKYO '95*, (Submitted). 2) Nakai & Hoshikawa (1991): Proc. *7th IACMAG*, (1), pp.655-660. 3) Hashiguchi (1980): *J. Appl. Mech, ASME*, Vol.102, No.2, pp.266-272

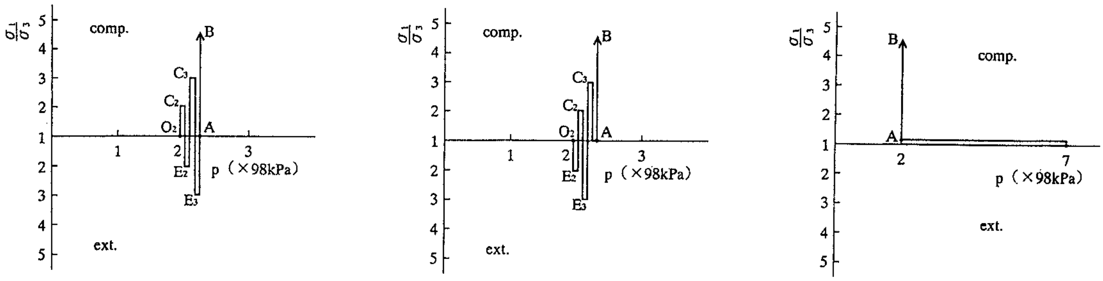

Figure 1: Stress paths of the drained triaxial tests.

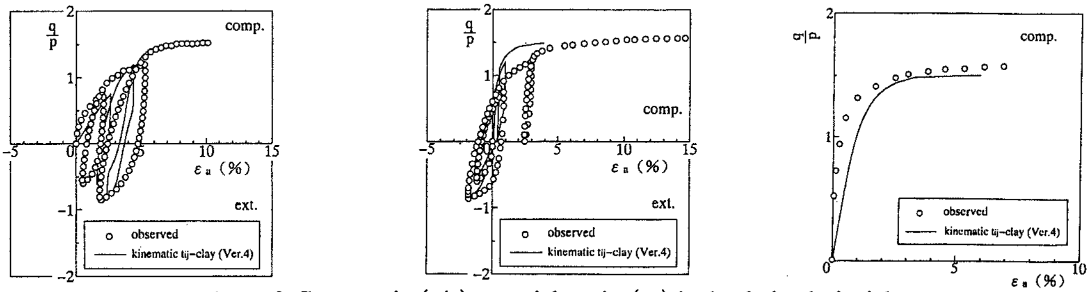

Figure 2: Stress ratio (q/p) vs. axial strain (ε_a) in the drained triaxial tests.

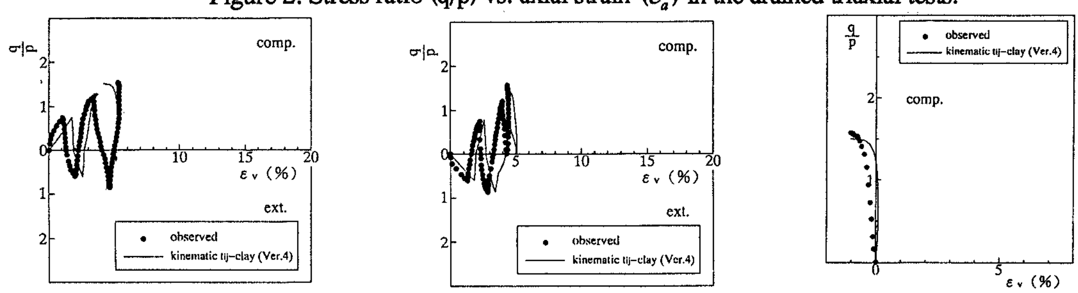

Figure 3: Stress ratio (q/p) vs. volumetric strain (ε_v) in the drained triaxial tests.

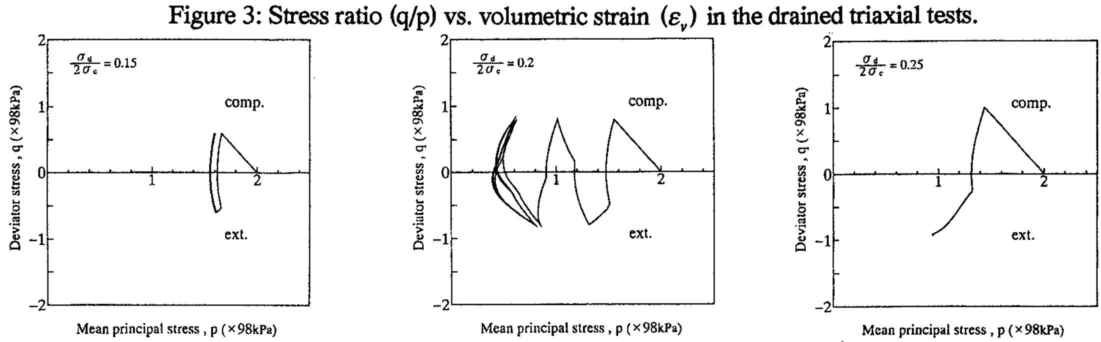

Figure 4: Calculated effective stress paths in the undrained triaxial tests.

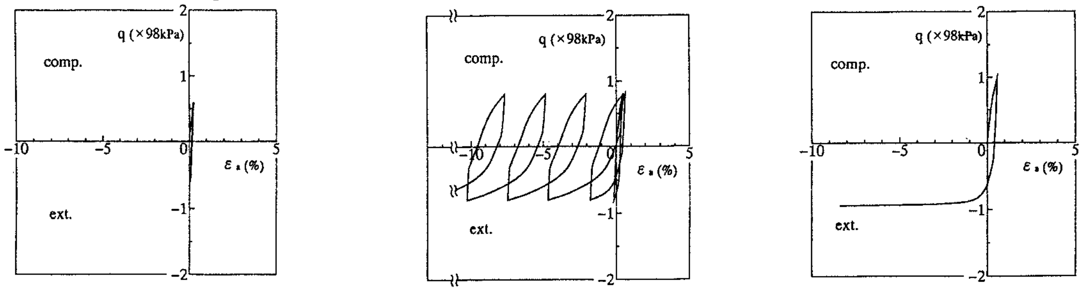

Figure 5: Calculated deviator Stress (q) vs. axial strain (ε_a) in the undrained triaxial tests.