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Behavior of Clay under Triaxial and Torsional Shear

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ABSTRACT:

An isotropic hardening clay model using modified stress tensor t_{ij} (Nakai and Mihara 1984) and nonlinear stress-dilatancy relation has been outlined here which well predicts shear behavior of clay under triaxial conditions but has some limitations under torsional shear. Hook's elastic constitutive relation has also modified to simulate a few observed facts.

MODEL OUTLINE:

Total strain increment is given by:

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

Observing positive dilatancy during unloading of anisotropically consolidated clay and to give an elastic relation consistent with t_{ij}-concept (Chowdhury et al., 1997), following elastic constitutive relation has been proposed by replacing $d\sigma_{ij}$ of Hook's elastic equation by dt_{ij}.

$$d\varepsilon_{ij}^{e} = \frac{1+\nu_e^*}{E_e^*} dt_{ij} - \frac{\nu_e^*}{E_e^*} dt_{kk}\delta_{ij} \quad (2)$$

Where, $\nu^* = \nu$ and $E_e^* = \frac{E_e}{\sqrt{3}} = \frac{\sqrt{3}(1-2\nu_e^*)t_N}{C_e}$ (3)

Plastic components of strain increments satisfying flow rule $\left(d\varepsilon_{ij}^{p(FR)}\right)$ and compressive isotropically $\left(d\varepsilon_{ij}^{p(IC)}\right)$ (Nakai and Matsuoka, 1986) are given by equations 4 and 5 respectively.

$$d\varepsilon_{ij}^{p(FR)} = \Lambda \frac{\partial f}{\partial t_{ij}} \quad (4)$$

$$d\varepsilon_{ij}^{p(IC)} = \frac{\delta_{ij}}{3} K\langle dt_N \rangle \quad (5)$$

Where, $K = C_p / t_{N1}$ (6)

t_{N1} is the value of t_N at the point of intersection of the yield surface with the t_N axis and $C_p = C_t - C_e$. C_t, C_e are the soil parameters and are given Table 1.

Yield function is given by assuming a nonlinear stress-dilatancy relation using t_{ij}-stress and strain increment variables and assuming associated flow rule as follows:

$$f = \ln\left(\frac{t_N}{t_{N0}}\right) - AX^{\beta} - \frac{\varepsilon_v^p}{C_p} = 0 \quad (10)$$

Stress-dilatancy relation is given by equation 11.

$$Y = d\varepsilon_{SMP}^{*} / d\gamma_{SMP}^{*} = 1/\left(\beta A X^{\beta-1}\right) - X \quad (11)$$

TEST RESULTS AND ANALYSES:

Strain controlled conventional triaxial tests at constant mean principal stress under compression (CT-C) and extension (CT-E) conditions and stress controlled hollow cylindrical tests (HC-3 through HC-6) have been performed on the laboratory reconstituted Fujinomori clay. Soil parameters are listed in Table 1. Experimental results of triaxial compression and extension tests and analyses are presented in figures 1 and 2 respectively, which show close agreement of strengths with experimentally observed ones with a slightly higher volumetric strains.

Hollow cylindrical test paths are shown in 3 and 4 and stress-strain relations (observed and predicted ones) are shown in figures 6 to 9. These figures show close prediction of volumetric strains but strength and stress-strain relation in general have some deviation from the observed responses. Strength predicted for tests HC-3 and HC-5 are less than those observed while predicted strengths for tests HC-4 and HC-6 are more than observed ones.

Table 1: Fujinomori clay parameters

$C_t = \lambda/(1+e_0)$	4.44×10^{-2}
$C_e = \kappa/(1+e_0)$	0.47×10^{-2}
φ'_{comp}	33.7°
β	1.40
ν_e	0.0

CONCLUSIONS:

Though this model gives very good predictions for conventional triaxial and true triaxial conditions (verified elsewhere) but under rotation of principal axes for example under torsional tests it could not predict properly. Probably this is not the model's drawback rather problems like rotation of principal stress axes should be considered as a boundary value problem.

Key word: Clay, constitutive models for soils, triaxial test, torsional shear test.

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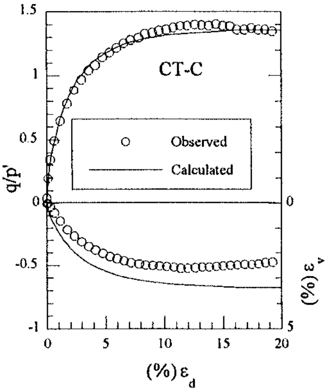

Fig.1: Stress-strain relation of triaxial compression test.

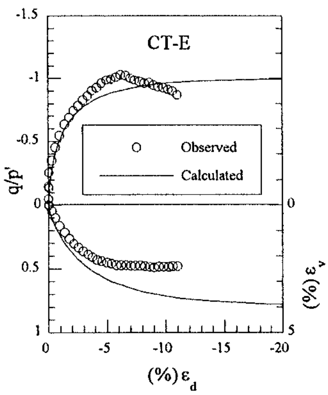

Fig.2: Stress-strain relation of triaxial extension test.

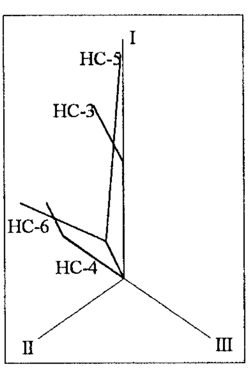

Fig.3: Stress paths of hollow cylindrical tests on octahedral plane

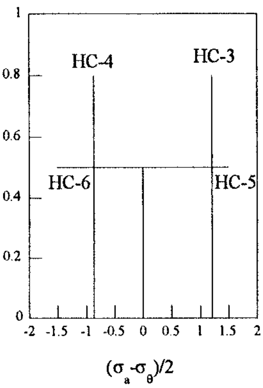

Fig.4: Stress paths of hollow cylindrical tests on $\tau_{a\theta}$ vs. $(\sigma_a - \sigma_\theta)/2$ plane

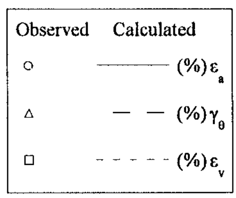

Fig.5: Legend of tests HC-3 to HC-6

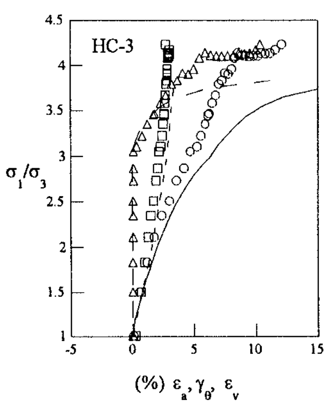

Fig.6: Stress strain relations of test HC-3

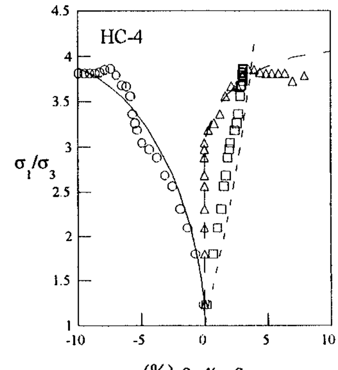

Fig.7: Stress strain relations of test HC-4

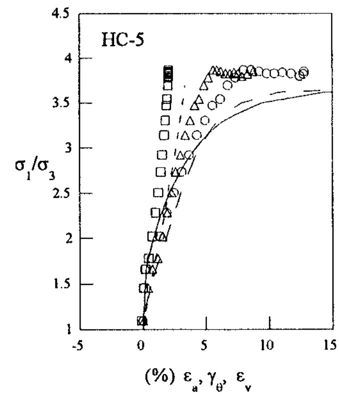

Fig.8: Stress strain relations of test HC-5

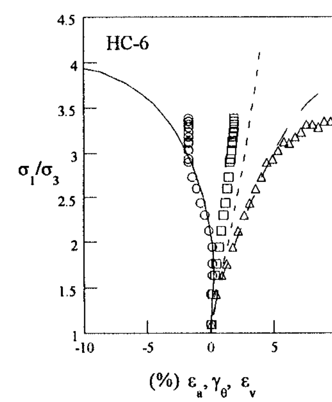

Fig.9: Stress strain relations of test HC-6

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