III－A18

A simple creep model for geomaterials and preliminary results for a compacted silty sand.

Filippo Santucci de Magistris, *IIS University of Tokyo*
Fumio Tatsuoka, *University of Tokyo*

Introduction: The stress-strain response of geomaterials during and after creep has an important role in the engineering practice, since, in the construction process, soils are often subjected to multiple constant stress stages lasting for different period. In this short paper a simple model is presented to predict creep strains for soils, using parameters which can be determined based on results from a triaxial test on a single specimen. The basic hypotheses of this model will be discussed with reference to the creep behaviour of a densely compacted silty sand.

The non linear creep model: The creep model is based on the assumption that soil obeys the isotach property (Suklje, 1969); that is, the stress state of a given soil element is a unique function of the current strain ε and strain rate $\dot{\varepsilon}$. The axial strain rate is assumed herein to influence the peak strength q_{max} following a simple power law: $q_{max} = a(\dot{\varepsilon})^b$ (1). Considering only plastic strains ε_p, a unique relationship is postulated to exist between the normalized stress $y=q/q_{max}$ and the normalized plastic strain $x=\varepsilon_p/\varepsilon_p^f$ (with reference to failure strain ε_p^f); that is: $y = f(x)$ (2) and so: $q = q_{max} f(x) = a(\dot{\varepsilon})^b f(x)$ (3). Assuming finally that both the plastic failure strain and the normalized stress-strain function (eq. 2) are independent of strain rate, we obtain: $\partial \varepsilon_f^p / \partial \dot{\varepsilon} = 0$ (4)and $\partial f(x) / \partial \dot{\varepsilon} = 0$ (5). A creep stage with $dq = 0$ is described, under the hypotheses, as: $dq = \left[\partial(q_{max} f(x)) / \partial \dot{\varepsilon}\right] d\dot{\varepsilon} + \left[\partial(q_{max} f(x)) / \partial \varepsilon_p\right] d\varepsilon_p = 0$ (6)or $\left[\left(\partial q_{max} / \partial \dot{\varepsilon}\right) \cdot f(x)\right] d\dot{\varepsilon} + \left[q_{max} \cdot \left(\partial f(x) / \partial \varepsilon_p\right)\right] d\varepsilon_p = 0$ (7).

Noting that: $\partial q_{max} / \partial \dot{\varepsilon} = b \cdot q_{max} / \dot{\varepsilon}$ (8) and $\partial f(x) / \partial \varepsilon_p = (\partial f(x) / \partial x) \cdot (\partial x / \partial \varepsilon_p) = (\partial f(x) / \partial x) / \varepsilon_p^f$ (9), we obtain: $\left[(b \cdot q_{max}) f(x)\right] d\dot{\varepsilon} / \dot{\varepsilon} + \left[q_{max} (\partial f(x) / \partial x) / \varepsilon_p^f\right] d\varepsilon_p = 0$ (10). By defining the creep coefficient as: $c_r = (b \cdot f(x) \cdot \varepsilon_p^f) / (\partial f(x) / \partial x)$ (11) we obtain the creep equation: $d\varepsilon = -c_r \cdot d\dot{\varepsilon} / \dot{\varepsilon}$ (12).

By integrating this equation from t=0, at the start of the creep stage, to t=*t*, the creep strains increment $\Delta\varepsilon(t)$ is obtained as: $\Delta\varepsilon(t) = (c_r)_{ave} \cdot \ln(T)$ (13), where $(c_r)_{ave}$ is the average creep coefficient between t=0 and t, and T is the normalized time defined as: $T = (\dot{\varepsilon}_0 / (c_r)_{ave}) \cdot t + 1.0$ (14) where $\dot{\varepsilon}_0$ is the strain rate at t=0, which is equal to the strain rate immediately before the creep stage in the present study.

Results for a compacted silty sand: Figure 1 shows the stress-strain curve obtained from an undrained triaxial compression test on in isotropic consolidated saturated specimen of a densely compacted silty sand (Metramo silty sand), whose physical and mechanical characteristics are reported elsewhere (see Santucci de Magistris et al., 1997). During the shearing, two undrained creep tests and a relaxation test were performed.

Key words: Creep model; Isotach; Triaxial tests; Silty sand
Address: IIS Univ. of Tokyo.7-22-1, Roppongi, Minato-ku, Tokyo 106. Tel: 03-3402 6321; Fax: 03-3479 0261

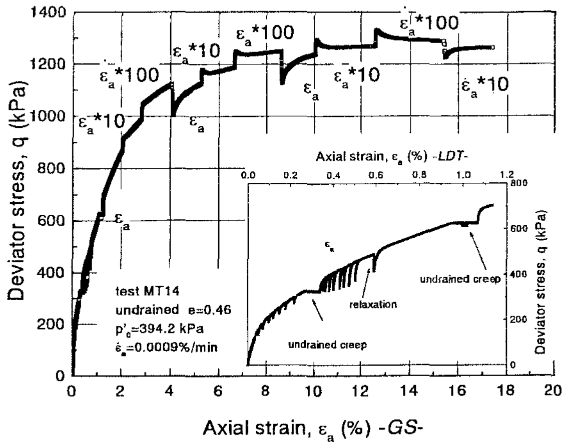

Figure 1. Stress-strain curve.

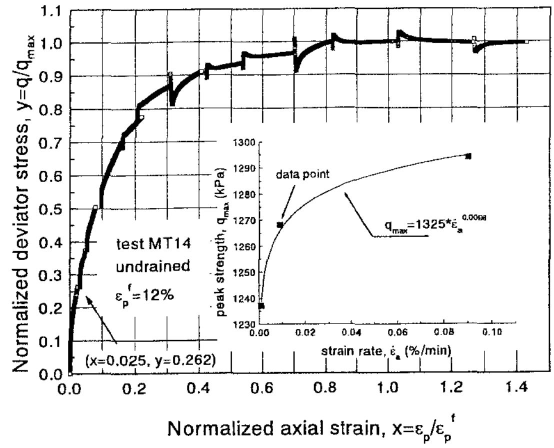

Figure 2. Normalized stress-strain curve.

Also, the strain rate was suddenly changed by one or two orders of magnitudes during monotonic loading. The same data are re-plotted in Figure 2 in the normalized form (eq. 2). The estimated changes in the peak strength q_{max} with the strain rate, evaluated using data of Fig. 1, is also shown in the inserted diagram with the fitted equation.

Figure 3 shows the axial strain increments, measured externally at the specimen cap with a gap sensor and locally with a couple of LDTs, plotted against time for the undrained creep at constant deviator stress q=326 kPa. In the same figure, the axial strain increment predicted by the creep model is reported, together with the parameters obtained from the experimental data.

Discussions: It may be seen from Fig. 2 that the test data are generally approximated by a single curve y=f(x), but some local "overshooting" and "undershooting" appear immediately after the soil is subjected to a sudden change in the strain rate. That is, the test material does not follow well the isotach behaviour at large strains. Perhaps due to the above and other factors, the model underestimated the creep strain increment; it may be seen, however, that the proposed creep model captures the main feature of the measured axial strain-time relationship. Finally, it should be noted that the creep strain increments are always overestimated when measured externally.

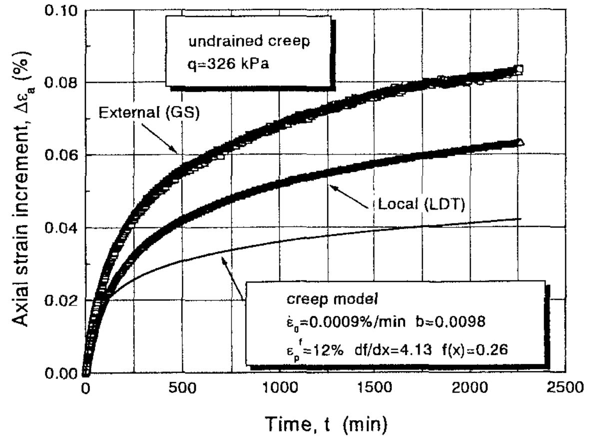

Figure 3. Measured and predicted axial strain increment during undrained creep.

Acknowledgment: The first author wish to thank JSPS for the given support.

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Santucci de Magistris, F., Silvestri F. and Vinale, F. (1997). *The influence of compaction on the mechanical behaviour of a silty sand*. To appear in Soils and Foundations.