ON THE STRESS RELAXATION OF CLAY

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SYNOPSIS

This is a report of theoretical and experimental researches on the stress relaxation of clay which play an important role in the phenomena of earth pressure. The assumption of a special model of clay is sufficient to express a stress relaxation which proceeds linearly with the logarithm of time and after a certain duration the stress relaxes to a final value. In the new type rheometer, the constant deformation is given to clay specimen and the relaxation of the internal stress is measured. Further, the thermal effect on stress relaxation of clay is discussed. Main results obtained here are as follows :

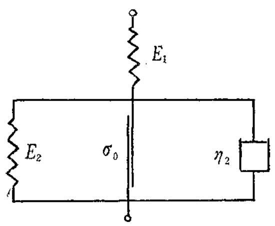

Fig. 1 Rheological model for clays.

The special rheological model of clay shown in Fig. 1 was developed to explain the viscosity, elasticity and internal resistance of clay (1956). It consists of a series coupling of a spring element E_1 and a modified Voigt element (E_2, σ_0, η_2) ; the dashpot η_2 represents the structural viscosity expressed in Eq. (1).

$$\eta_2 = 1/A_2 \cdot \sinh\left(\frac{B_2\sigma_2}{\sigma-\sigma_0}\right) \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots (1)$$

where σ is total stress, σ_2 is stress added to the dashpot, σ_0 is lower yield value and A_2, B_2 are rheological constants.

The relaxation of stress in clay under constant initial deformation, viz. the relation between total stress σ and time t is approximately given as

$$\int_{u_0}^{u} \frac{1}{u}\cdot \exp(u)\,du = C\cdot t$$

where

$$\left.\begin{aligned} u_0 &= B_2\frac{E_2}{E_1} \\ u &= \frac{B_2E_2}{(\sigma-\sigma_0)}\left(\varepsilon_0 - \frac{\sigma_0}{E_1}\right) \\ C &= \frac{A_2}{2}\cdot E_1 \cdot \exp\left\{B_2\left(1+\frac{E_2}{E_1}\right)\right\} \end{aligned}\right\} \cdots\cdots (2)$$

and at $t\to\infty$

$$\sigma_{t\to\infty} = \frac{E_1E_2}{E_1+E_2}\cdot\varepsilon_0 \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (3)$$

where E_1 and E_2 are elastic moduli of clay and ε_0 is constant initial strain.

The results of the stress-time relationships numerically calculated by Eq. (2) applying model constants found by the experiments are shown in Fig. 2 for various values of ε_0, and these calculated curves are represented by approximate straight lines on the semilogarithmic paper. When the internal stress is entirely transmitted to the spring elements E_1 and E_2, stress relaxation ceases.

The result of stress relaxation test under the undrained condition is given in Fig. 3, this shows that stress decreases proportionately to the logarithm of time and finally reaching a finite value as shown in Fig. 2.

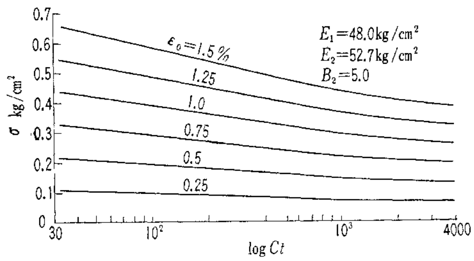

Fig. 2 Calculated stress-relaxation courves.

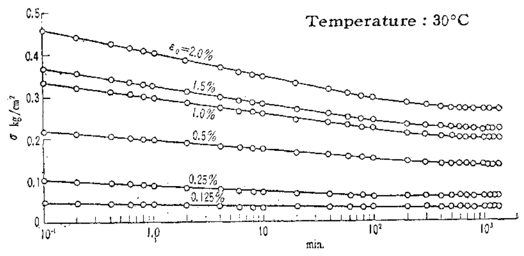

Fig. 3 Relaxation of stresses.

The elastic moduli of clay E_1 and E_2 can be computed from the following equations : $E_1=\sigma_{t=0}/\varepsilon_0$, $E_2=\sigma_{t=0}\cdot\sigma_{t\to\infty}/(\sigma_{t=0}-\sigma_{t\to\infty})\cdot\varepsilon_0$. The elastic moduli thus calculated are shown in Fig. 4, this shows that if any constant deformation exceeding the critical value is applied to clay, the clay will fail.

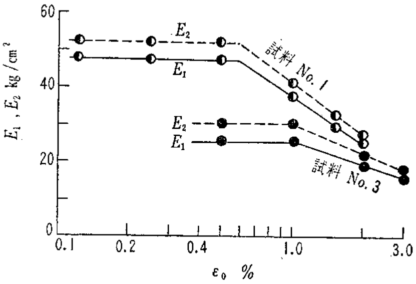

Fig. 4 Elastic moduli related to constant initial strain.

The result of tests on thermal effect of stress relaxation of clay is shown in Fig. 5. In Fig. 6, each stress obtained from Fig. 5 is plotted against the temperature for the various constant values of the time. This figure shows that the stress decreases with the increase of temperature.

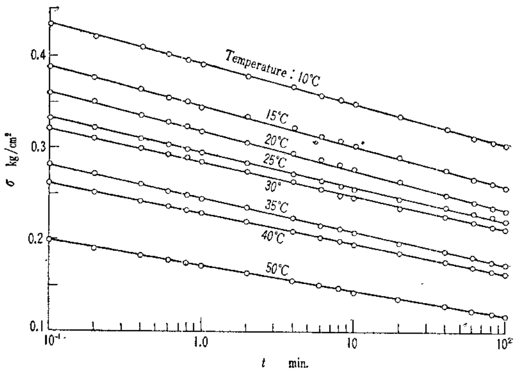

Fig. 5 Thermal effect on stress-relaxation.

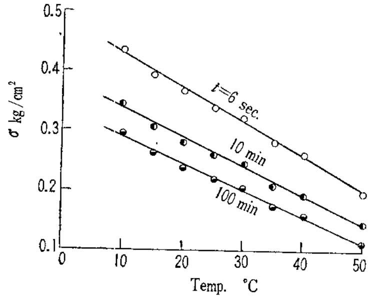

Fig. 6 Stress related to temperature.