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Experimental Study on Creep of Clay around a Single Pile

by

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Introduction

When a friction pile driven into soft clay strata is loaded vertically, settlement will be caused and the clay around the pile will be subjected to shearing creep. The basic features of a typical creep curve (Fig. 1) consist of four parts: initial deformation, representing the strain which occurs on loading; primary or transient creep, representing the region of decreasing creep rate; secondary or steady state creep, representing the region of relatively constant creep rate; and tertiary creep, representing the final stage leading to failure. Under relatively small skin frictions as characterized by f_1 (Fig. 2), any settlements that take place may be small and may cease after some period of time. Therefore secondary and tertiary creep do not occure and the creep is said to be damped. Under skin frictions of higher intensity, f_2(Fig. 2), settlements may continue for a long time. In many soils, continued application of stress may result in an acceleration in the creep rate followed by complete failure.

The purpose of this paper is to investigate the skin friction-pile movement-time relationship over the range of the primary creep.

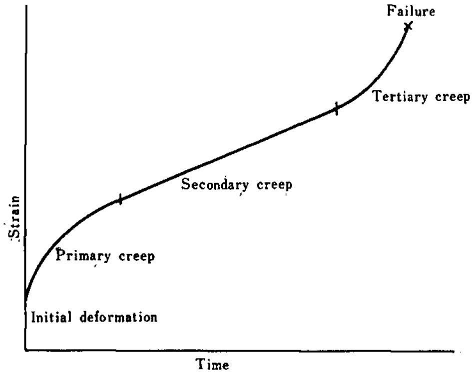

Fig. 1. Typical creep cruve.

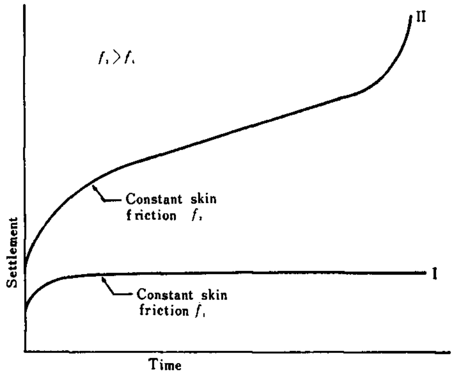

Fig. 2. Typical behavior of pile under constant skin friction.

Test equipment and method

Some of index properties of clay used are as follows: liquid limit $=55\%$; plastic limit$=23\%$; specific gravity$=2.63$.

The test equipment is shown in Fig. 3. The aluminium pile 35 mm in outside diameter is pulled up by the pulley. The surface of the pile is comparatively smooth. The cylindrical container is 30 cm in inside diameter and 70 cm deep. The movemeent of the pile was measured by the dial gauge.

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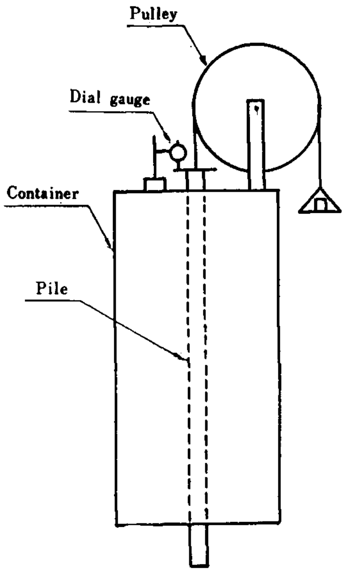

Fig. 3. Test equipment.

The experiments were performed after one hour from the time when the cryindrical container was stuffed with the clay. The water content of the clay was about 60%, and its temperature was kept about 20°C.

The skin friction f is experessed by

$$f=(F-F_0)/A$$

where F = pulling force in the case where the container is stuffed with the clay,

F_0 = pulling force in the case where the pile only is about to move, when the container is not stuffed with the clay,

A = surface area of pile.

The experiments were performed under skin friction values of 0.57, 0.69, 0.78, and 0.86 g/cm^2.

Test results and Consideration

The relationships between the pile movement γ and time t is shown in Fig. 4 for skin friction values of 0.86, 0.78, 0.69, 0.57 g/cm^2. As the experimental values are very scattered with the exception of the curve for $f=0.57$ g/cm^2, the curves for $f=0.86$, 0.78, 0.69 g/cm^2 are shown by the minimum and maximum values. The curves (1), (3), (5) are maximum values and the curves (2), (4), (6) are minimum values. At skin frictions of $f=0.86$ and $f=0.78$ g/cm^2, the pile was pulled up. At skin friction of $f=0.69$ g/cm^2, two cases was obtained. In first case the pile was pulled up and in second case the pile moved very slowly for a long time. Therefore skin friction value of $f=0.69$ g/cm^2 seems to be critical value. It is an unstable phenomenon to pull up the pile by critical skin friction or any skin friction near critical value; therefore, the experimental values were very scattered.

As is evident from Fig. 4, the pile movement reaching from 50×10^{-3} mm to 100×10^{-3} mm, the velocity of pile increases rapidly.

Fig. 5, which is obtained from Fig. 4, shows the plot of the velocity of pile v versus time t. The straight lines in Fig. 5 is nearly parallel mutually. This straight lines are expressed by the expression

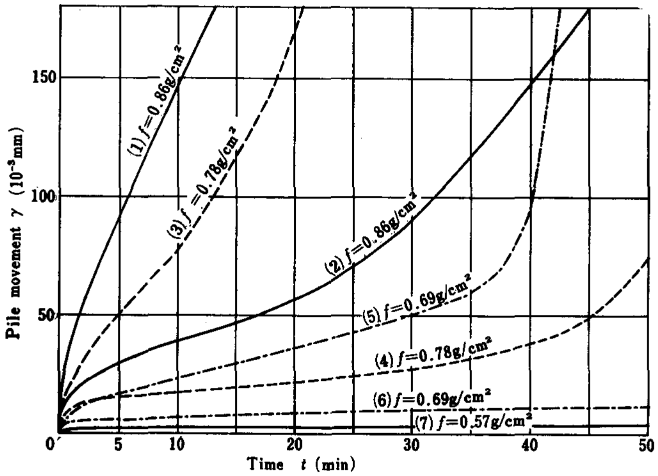

Fig. 4. Pile movement versus time relationships.

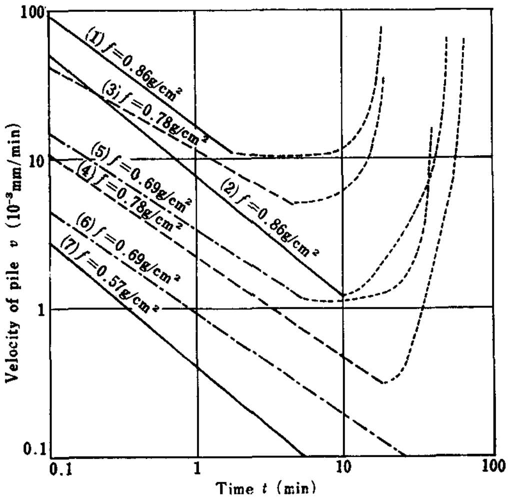

Fig. 5. Velocity of pile versus time relationships.

$$\log(v/v(t_1, f)) = -m\cdot\log(t/t_1) \qquad (1)$$

where v=velocity of pile at any time, t;

$v(t_1, f)$ = velocity of pile at unit time, a function of skin friction, f;

m = absolute value of slope of the straight line on the log-velocity of pile versus log-time plot;

t_1 = unit time, e.g., 1 min.

Figs. 6 and 7, which are obtained from straight lines (1), (3), (5) (7) and (2), (4), (6), (7) in Fig. 5 respectively, show the plot of the velocity of pile versus skin friction. A nearly linear relationship is found between logarithm of the velocity of pile and skin friction. The straight lines in Figs. 6 and 7 can be expressed by

$$\log\frac{v}{v(t, f_0)} = af \qquad (2)$$

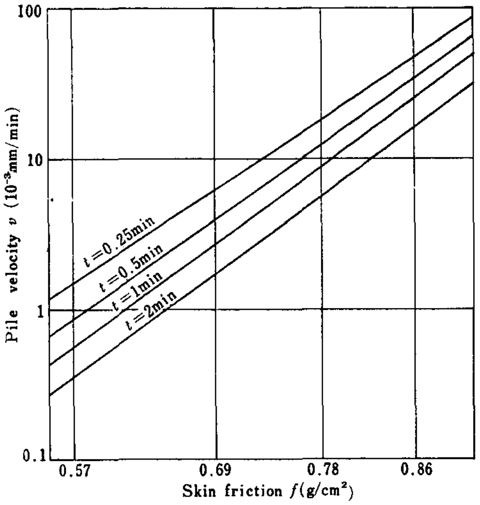

Fig. 6. Variation of pile velocity with skin friction for maximum values (1), (3), (5), (7).

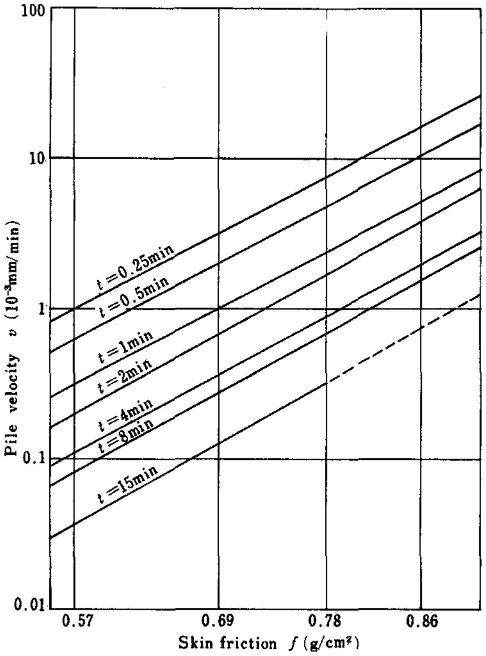

Fig. 7. Variation of pile velocity with skin friction for minimum values (2), (4), (6), (7).

where $v(t, f_0)$ = fictitious value of velocity of pile at $f=0$, a function of t;
t = time after start of creep, or time after application of load;
a = value of slope of the linear portion of the logarithm-pile velocity versus skin friction plot.

Eliminating v from Eqs. 1 and 2 gives

$$\log v(t_1, f) - m \log (t/t_1) = \log v(t, f_0) + af \tag{3}$$

For the case of $f=0$, this equation may be rewritten as

$$\log v(t, f_0) = \log v(t_1, f_0) - m \log (t/t_1) \tag{4}$$

where $v(t_1, f_0)$ = value of pile velocity obtained by projecting the straight-line portion of the relationship between log-pile velocity and skin friction at unit time (t_1) to a value of $f=0$.

Thus, Eq. 2 becomes

$$\log v = \log v(t_1, f_0) + af - m \log (t/t_1) \tag{5}$$

which may be written as

$$v = v(t_1, f_0) \cdot 10^{af} \cdot (t_1/t)^m \tag{6}$$

or

$$v = A \cdot 10^{af} \cdot (t_1/t)^m \tag{7}$$

where $A = v(t_1, f_0)$.

A general relationship between pile movement and time may be obtained by integration of Eq. 7. The solution is

$$\gamma = A\cdot 10^{\alpha f}\cdot t_1^m\left(\frac{1}{1-m}\right)\cdot t^{1-m}+C,\ (m\neq 1) \tag{8}$$

The constant of integration C in Eq. 8 can be evaluated from a known value of pile movement at some known value of time, for instance, unity. If γ_1 is the pile movement at unit time $t=t_1$, the constant of integration C will be

$$C = \gamma_1-\frac{A}{1-m}\cdot 10^{\alpha f}\cdot t_1 \tag{9}$$

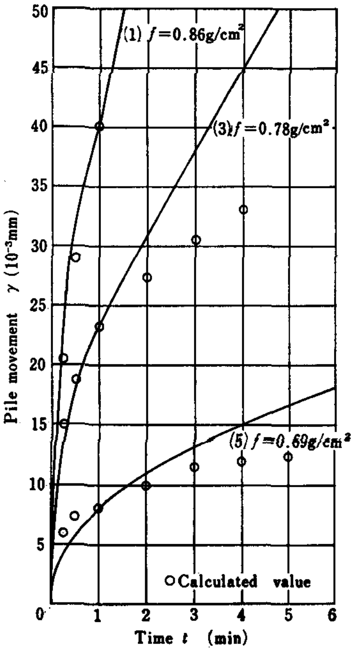

Fig. 8. Comparison between calculated and observed creep for upper limits (1), (3) (5).

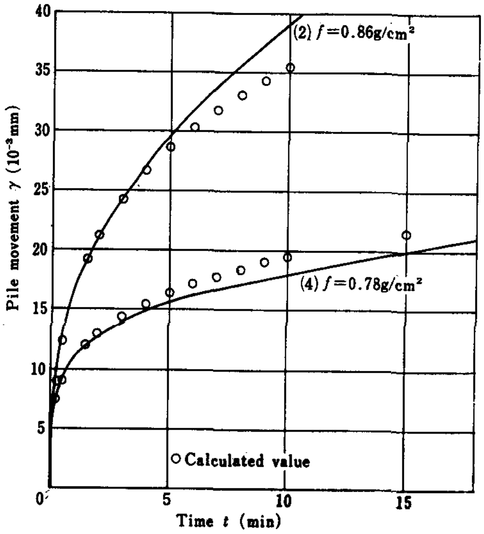

Fig. 9. (a). Comparison between calculated and observed creep for lower limits (2), (4).

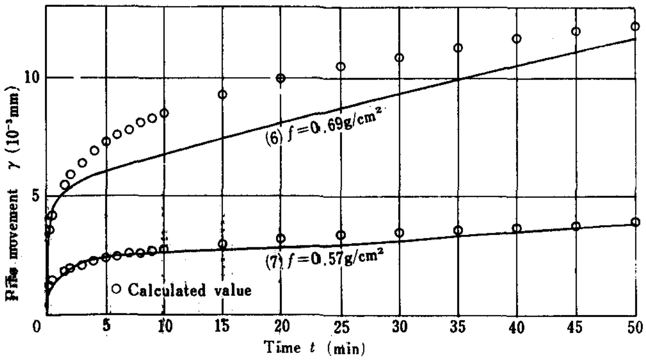

Fig. 9(b). Comparison between calculated and observed creep for lower limits (6), (7).

Thus, the solution given by Eq. 8 can be rewritten as

$$\gamma = \gamma_1 + \frac{A}{1-m} \cdot 10^{\alpha f} \cdot t_1 \left\{ \left(\frac{t}{t_1} \right)^{1-m} - 1 \right\}, \ (m \neq 1) \tag{10}$$

where γ = pile movement at any time t.

The values of parameters m, α, and A are as follows:
for the curves (1), (3), (5), (7) (maximum values) in Fig. 3,
$m=0.71$, $\alpha=5.5$, $A=3.2 \times 10^{-4}$;
for the curves (2), (4), (6), (7) (minimum values) in Fig. 3,
$m=0.78$ $\alpha,=4.3$, $A=1.26 \times 10^{-3}$.
Comparison of the experimental results with the calculated results using Eq. 10 for upper limits are shown in Fig. 8, for lower limits in Fig. 9. It may be seen that the agreement is generally good over a range of primary creep. Therefore, the calculations based on Eq. 10 seem to lead to satisfactory results.

Acknowledgment

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