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A METHOD FOR ESTIMATING THE CONSOLIDATION OF A NORMALLY CONSOLIDATED CLAY OF SOME AGE

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ABSTRACT

The Paper describes a method for estimating the one-dimensional consolidation of an aged clay. First, a mathematical model of consolidation is developed by taking account of the properties of aged clays such as preconsolidation and secondary compression effects, and the numerical solutions are presented for some particular cases. By comparison with published experimental results, it is demonstrated that the theory can explain extensively the consolidation characteristics of aged clays. Successively, the determination of the index properties of soil which appear in the theory is considered. The applicability of the theory to practical problems is inferred by comparing with results of model tests in laboratory. Consequently, it is found that the estimate of consolidation by means of the proposed method is fairly surpassing.

Key words: consolidation, fully saturated soil, pore pressure, time effect, secondary compression, settlement
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INTRODUCTION

The Terzaghi theory of one-dimensional consolidation has been familiarly employed with the purpose of predicting the consolidation of a fully saturated soil. However, it has no information in terms of the effects of quasi-preconsolidation and secondary compression on consolidation. It can be therefore said that the theory is valid only for the consolidation of a soil or the case of consolidation in which the effects are negligible. It means that the Terzaghi theory is by no means capable of explaining rationally the consolidation of an aged soil which has been previously subjected to secondary compression. Some attempts have been therefore made to develop consolidation theories which consider secondary compression and a quasi-preconsolidation effect and are applicable to consolidation problems of aged soils.

Garlanger (1972) has proposed a theory of consolidation for soils exhibiting creep under constant effective stress based on the soil model described by Bjerrum. Mesri and Rokhsar (1974) have developed a theory of one-dimensional consolidation by considering finite strain, the variation of permeability, and the effects of a critical pressure and secondary compression.

In such theories, it is assumed that no peculiar properties of an aged soil appear under the application of an effective pressure less than the quasi-preconsolidation pressure,

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except for the compressibility. However, some results of laboratory consolidation tests on aged clays indicate that the initial behavior of excess pore-water pressure observed is somewhat different from that predicted from these theories when a hydrostatic pore-water pressure is not high, and suggest that the influence of adsorbed moisture cannot be neglected essentially at the early stage of consolidation.

In this Paper, a theory of the one-dimensional consolidation of an aged clay is developed by taking account of the effect of adsorbed moisture together with the relationship between void ratio e and effective pressure p' deduced by the author (1979), and a method for estimating the consolidation is proposed.

DEVELOPMENT OF THEORY

In the range of normal consolidation, it may be reasonable to assume that the flow of excess pore-water within a soil is governed by Darcy's law and that the rate of dissipation of the pore-water from an element of the soil is equal to the rate of volume change of the element. Then, we obtain:

$$\frac{1}{1+e_0}\left(\frac{\partial e}{\partial t}\right)=\frac{1}{\gamma_w}\frac{\partial}{\partial z}\left(k\frac{\partial u}{\partial z}\right) \qquad (p_c'\leqslant p'\leqslant p_f') \tag{1}$$

in which e_0=initial void ratio; k=coefficient of permeability; γ_w=weight of water in unit volume; u=excess pore-water pressure; t=elapsed time; z=vertical coordinates; p_c'= quasi-preconsolidation pressure, and p_f'=final effective pressure. However, it is doubtful whether Eq. (1) is valid under an effective pressure less than p_c', if considering the influence of adsorbed moisture. It seems that the viscous resistance of adsorbed moisture films against the application of pressure increment or the interaction between adsorbed moisture and free pore-water consequent upon a sudden increase in pore-water pressure must be additionally taken into account.

It has been revealed in some studies that an increase in pore-water pressure is observed in specimens which have sat under undrained conditions for some periods after consolidation (e.g. Walker, 1969). Referring to the published experimental results, the relationship between the increase in pore-water pressure Δu and the elapsed time t may be approximately expressed as follows:

$$\Delta u=\alpha\ \Delta\log_{10}t \tag{2}$$

in which α=a coefficient which is time and structure dependent. It is of interest to contrast Eq. (2) with the well-known relationship concerning secondary compression:

$$\Delta e=-C_\alpha\ \Delta\log_{10}t \tag{3}$$

where C_α=time rate of secondary compression. By considering that such a phenomenon does not occur in a sand, it can be inferred that the pore-water pressure buildup, which causes the change in void ratio Δe under a drained condition, i.e. the secondary compression, has special reference to the existence of adsorbed moisture. It is now assumed that when an aged clay is consolidated this kind of phenomenon occurs under an effective pressure less than p_c'. However, the mechanical interaction between adsorbed moisture and free pore-water may reverse as contrasted with the above case, so that the negative pore-water pressure may be built up. On the other hand, the excess pore-water pressure induced by the application of pressure increment may be in fact affected by the viscous resistance of adsorbed moisture films which has developed during the preceding secondary compression, yet it is now assumed for convenience sake that the influence is negligible. Thus, Eq. (1) is modified as follows:

$$\frac{1}{1+e_0}\left(\frac{\partial e}{\partial t}\right)=\frac{1}{\gamma_w}\frac{\partial}{\partial z}\left(k\frac{\partial u}{\partial z}\right)+\kappa R(t) \qquad (p_0'\leqslant p'\leqslant p_c') \tag{1$'$}$$

where κ=a coefficient, which is related to the compressibility of an aged clay on the application of pressure increment under an undrained condition and may be dependent upon time and stress histories of the clay; R=rate of the decay of excess pore-water pressure under an undrained condition, and p_0'=initial effective pressure. In practice the value of κ can be determined in advance by the measurements of vertical strain and pore-water pressure within an aged clay under an undrained loading condition. It should be herein noted that the secondary compression is time-dependent (consolidation) while the volume change due to the transmutation of adsorbed moisture is instantaneous (compression).

Consolidation is conveniently separated into two components, i.e. primary and secondary consolidations. It is supposed that the primary consolidation is entirely caused by the dissipation of excess free pore-water from a soil and is a unique function of effective pressure only. The relationship between void ratio and effective pressure may be expressed for the component of primary consolidation as follows:

$$\left.\begin{array}{ll} e_0-e^{(p)}=C_{cq}\log_{10}(p'/p_0') & (p_0'\leqslant p'\leqslant p_c') \\ e_0-e^{(p)}=C_{cq}\log_{10}(p_c'/p_0')+C_c\log_{10}(p'/p_c') & (p_c'\leqslant p'\leqslant p_f') \end{array}\right\} \tag{4}$$

or

$$\left.\begin{array}{ll} \delta e^{(p)}=-\dfrac{0.434\,C_{cq}}{p'}\delta p' & (p_0'\leqslant p'\leqslant p_c') \\ \delta e^{(p)}=-\dfrac{0.434\,C_c}{p'}\delta p' & (p_c'\leqslant p'\leqslant p_f') \end{array}\right\} \tag{4$'$}$$

in which C_{cq}=quasi-compression index; C_c=compression index, and $\delta e^{(p)}$=change in void ratio owing to primary consolidation. On the other hand, the secondary consolidation is generally defined as the compression which continues to occur after excess pore-water pressure has substantially dissipated. However, in the author's preceding paper (1979), it has been revealed that the secondary consolidation results partly from the failure of film bond between soil particles and therefore occurs even during the stage that excess pore-water is just dissipating. The secondary consolidation is secondarily related to the excess pore-water pressure within a clay. Accordingly, it is more reasonable to express the development of secondary consolidation as follows:

$$\left.\begin{array}{ll} \delta e^{(s)}=0 & (p_0'\leqslant p'\leqslant p_c') \\ \delta e^{(s)}=-C_\alpha(e_c-e^{(p)})/(e_c-e_f)\,\delta\log_{10}t & (p_c'\leqslant p'\leqslant p_f') \end{array}\right\} \tag{5}$$

in which $\delta e^{(s)}$=change in void ratio due to secondary consolidation; C_α=coefficient of secondary compression; e_c and e_f=void ratios corresponding to p_c' and p_f' in an e–$\log_{10}p'$ diagram respectively (see Fig. 1). Therefore, $(e_c-e^{(p)})/(e_c-e_f)$ can be expressed in terms of effective pressure as $\log_{10}(p'/p_c')/\log_{10}(p_f'/p_c')$. The rate of change in void ratio $(\partial e/\partial t)$ can be replaced with the sum of $(\partial e/\partial p')_{t=\mathrm{const}}(\partial p'/\partial t)$ and $(\partial e/\partial t)_{p'=\mathrm{const}}$, since e is a function of both t and p'. Consequently, the governing equations of consolidation are, if an applied load is constant:

$$\left.\begin{array}{ll} \dfrac{\partial e}{\partial t}=-\dfrac{0.434\,C_{cq}}{p'}\dfrac{\partial p'}{\partial t} & \\ \dfrac{1}{1+e_0}\left(\dfrac{\partial e}{\partial t}\right)=-\dfrac{1}{\gamma_w}\dfrac{\partial}{\partial z}\left(k\dfrac{\partial p'}{\partial z}\right)-\kappa S(t) & (p_0'\leqslant p'\leqslant p_c') \\ \dfrac{\partial e}{\partial t}=-\dfrac{0.434\,C_c}{p'}\dfrac{\partial p'}{\partial t}-\dfrac{0.434\,C_\alpha h(p')}{t} & \\ \dfrac{1}{1+e_0}\left(\dfrac{\partial e}{\partial t}\right)=-\dfrac{1}{\gamma_w}\dfrac{\partial}{\partial z}\left(k\dfrac{\partial p'}{\partial z}\right) & (p_c'\leqslant p'< p_f') \end{array}\right\} \tag{6}$$

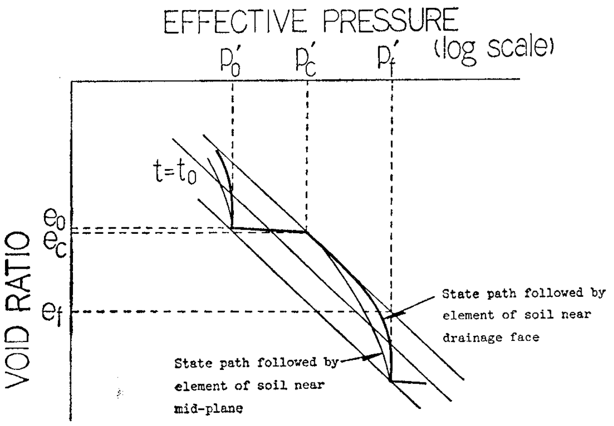


Fig. 1. Relationship between void ratio and logarithm of effective pressure for an aged clay

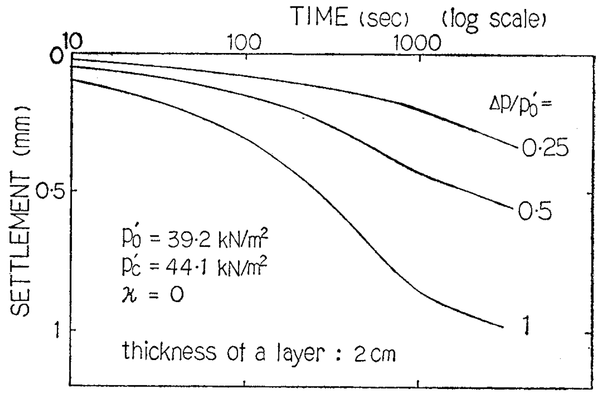


Fig. 2. Theoretical effect of load increment ratio on consolidation

in which $h(p')=\log_{10}(p'/p_c')/\log_{10}(p_f'/p_c')$, and $S(t)$=rate of the increase in effective pressure under an undrained condition.

NUMERICAL SOLUTIONS

The one-dimensional consolidation of an aged clay which occurs under a given condition can be estimated on the basis of Eq. (6). A simple way of solving Eq. (6) may be the use of a finite difference method. In the present paper, the method which has been introduced by Abbott (1960) is taken. Some of numerical results will be shown for particular cases.

Suppose the case that a uniform pressure increment of Δp $(=p_f'-p_0')$ is applied newly to a layer of clay, which has permeable top and bottom faces, and has been subjected to the pressure p_0' and exhibits the quasi-preconsolidation effect under the application of the effective pressure less than p_c'. The following index properties of soil are in principle assumed on computations:

$C_c=0.650$; $C_{cq}=0.033$; $C_\alpha=0.010$; $e_0=2.7$, and $k=1.0\times10^{-7}$(cm/s) (=const.)

Table 1. Comparison between a numerical and an analytical solutions

Time (s)	Solution by finite difference method (1/100 mm)	Solution by analytical method (1/100 mm)
10	10.9	11.0
60	26.9	26.9
120	37.9	38.0
180	46.4	46.5
300	59.8	59.8
600	81.3	81.2
900	92.7	92.6
∞	105.8	105.8

$C_c=0.650$; $k=6.37\times10^{-6}/p'$ (cm/s); $e_0=2.7$; $p_0'=39.3$ (kN/m^2); $p_f'=78.4$ (kN/m^2) thickness of a clay layer=2 (cm); top and bottom permeable; the coefficient of consolidation $c_v=8.53\times10^{-4}$ (cm^2/s)

First, in Table 1 is shown a numerical solution for the consolidation of a young clay $(p_0'=p_c')$ exhibiting no secondary consolidation $(C_\alpha=0)$, together with the famous analytical solution by Terzaghi. It is known that the solutions of time-settlement which are obtained by assuming both a linear relationship of e-$\log_{10}p'$ and a relation of $k\cdot p'$=constant become identical to the Terzaghi solutions. It can be therefore said that the finite difference method used gives satisfactory accuracy for the present numerical computations.

In Fig. 2, the time-settlement curves are presented for various load increment ratios, which have been computed for the case when a load increment of different magnitude is applied to a particular aged clay.

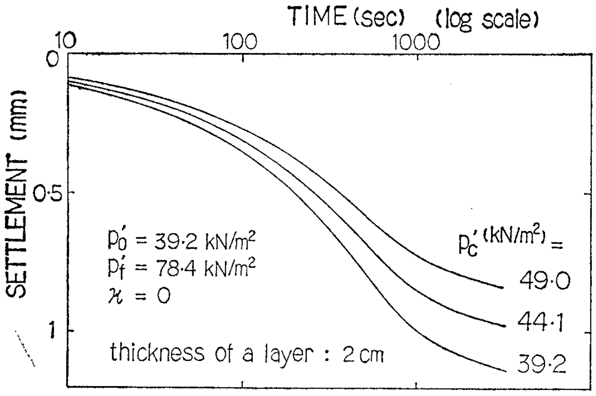


Fig. 3. Theoretical effect of quasi-preconsolidation pressure on consolidation

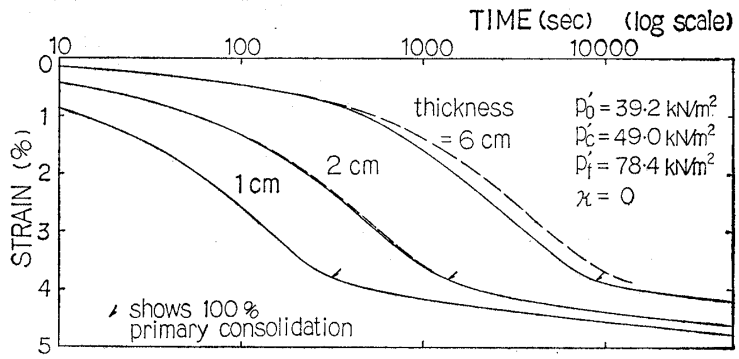


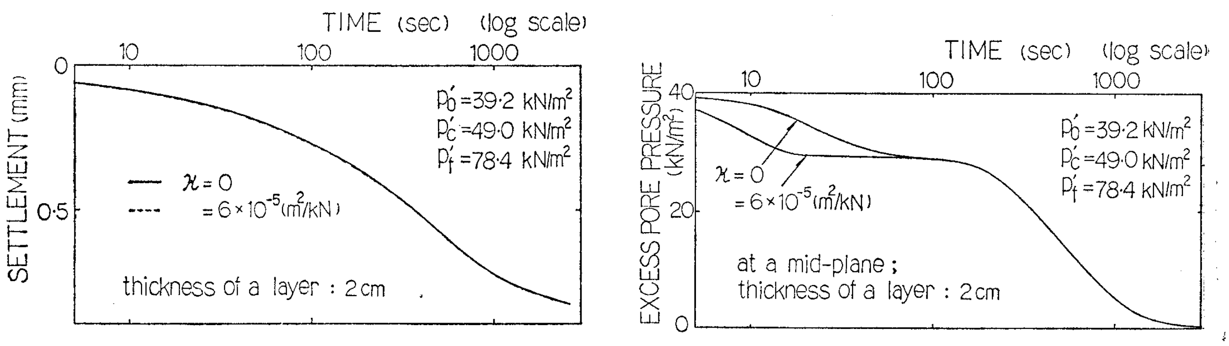
Fig. 4. Theoretical effect of thickness on consolidation

It can be seen that the consolidation of an aged clay is sensitively influenced by load increment ratios.

Fig. 3 shows consolidation curves for the case when the load increment of prescribed magnitude is applied to aged clays, which will exhibit different quasi-preconsolidation effects in degree. It is found that consolidation is delayed as a quasi-preconsolidation pressure is larger, loading conditions remaining fixed. Herein it is reasonable to assert that the gain in quasi-preconsolidation pressure results from the further development of secondary consolidation or the longer duration of sustained loading. Therefore, it should be noted that Fig. 3 illustrates the effect of loading duration on the following consolidation process.

Fig. 4 shows the relationships of time-vertical strain which refer to the consolidation of clay layers with different thickness. It is well-known that consolidation is delayed as the thickness of a clay layer is larger and the Terzaghi theory predicts that the delay is proportional to the square of thickness. However, in the numerical results, the proportionality cannot be found even at the stage of primary compression by reason of the effect of secondary consolidation.

In Fig. 5, the effect of κ on consolidation is presented. The numerical results have been obtained by assuming $S(t)=\partial p'/\partial t$ in Eq. (6) (although the meaning of this assumption is explained later). The used value of κ may be appropriate for most of aged clays. It can be seen that κ has less influence on the time-settlement curve but considerable influence on the initial behavior of mid-plane pore-water pressure.



(a) (b)

Fig. 5. Theoretical effect of a coefficient κ on consolidation settlement and mid-plane pore-water pressure

COMPARISONS WITH EXPERIMENTAL RESULTS

The numerical solutions obtained so far are compared with some of published experimental results. The comparisons are performed as concerns the effects of a load increment ratio, loading duration and thickness of a clay, which are closely related to the consolidation characteristics of an aged clay.

Effect of Load Increment Ratio

Fig. 6 presents the effect of a load increment ratio on a shape of dial reading-time curves which Leonards and Girault (1961) have obtained from consolidation tests on an undisturbed Mexico City clay. For a relatively large load increment ratio, the curve is similar to that obtained from the Terzaghi theory, with the exception of secondary compression. However, when the load increment ratio becomes smaller, the shape of curves is considerably changed. Compared with Fig. 2, it can be found that there exists a similarity between the theoretical and the experimental results. This matter suggests that the present theory can explain the influence of a load increment ratio on consolidation. It is therefore inferred that this influence is virtually attributed to a quasi-preconsolidation effect. If secondary consolidation is neglected, the consolidation curve of a young clay takes the almost same shape as the Terzaghi theory predicts, irrespective of the magnitude of load increment ratios.

Effect of Loading Duration

It is known that consolidation is greatly influenced by duration of sustained loading. Fig. 7 reproduces the experimental verification made by Northey and Thomas (1965). Curves A and B indicate the relationships between average consolidation and logarithm of time which have been obtained from 20 minutes and 24 hours loading cycle tests respectively. It can be seen that longer loading duration has a tendency to retard the following consolidation. The same tendency is also seen in the investigation carried out by the author (1977). Compared with the theoretical results shown in Fig. 3, it can be recognized that the present theory is capable of predicting this delay of consolidation.

Effect of Thickness

Fig. 8 reproduces the observations in consolidation tests of clay layers with different thickness which Aboshi (1973) has conducted. It is seen in the Figure that the vertical strain at 100% primary consolidation is different according to the thickness, which the Terzaghi theory cannot predict by any means. As compared with the numerical results

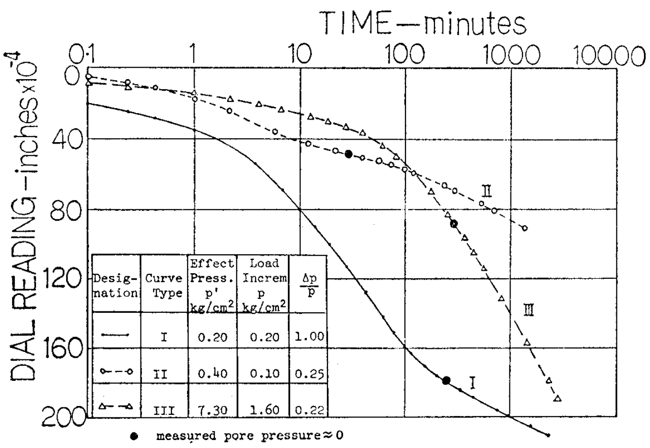


Fig. 6. Result from consolidation tests conducted by Leonards and Girault

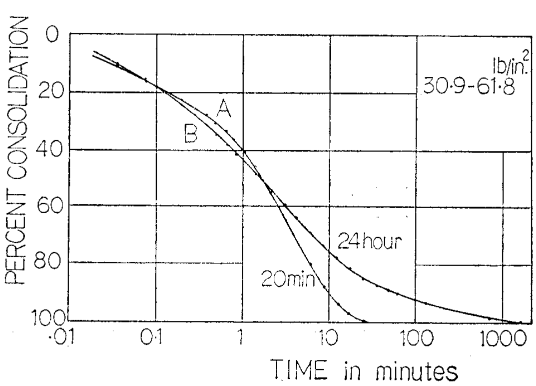


Fig. 7. Result from consolidation tests carried out by Northey and Thomas

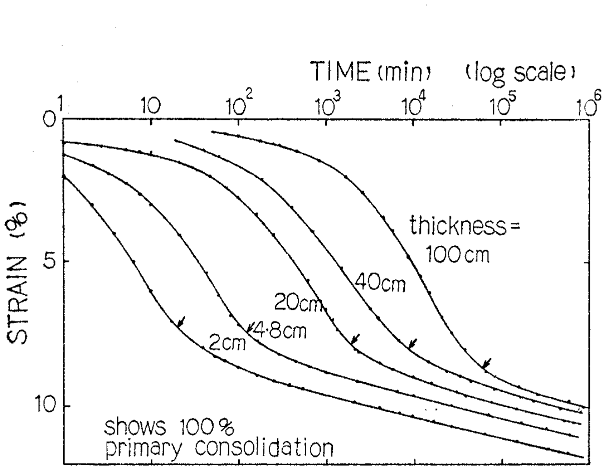


Fig. 8. Observations in consolidation tests conducted by Aboshi

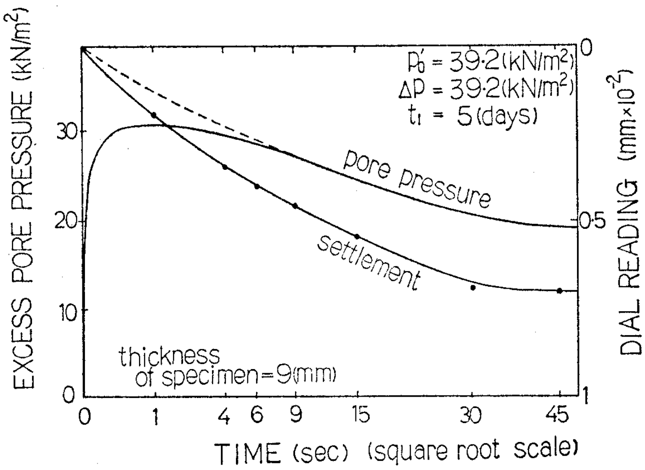


Fig. 9. Vertical displacement and mid-plane pore-water pressure observed in an undrained loading test

in Fig. 4, it will be seen that the characteristics of time–vertical strain observed in the experiment can be fairly explained by the present theory.

The reliability of the theory has been examined by taking notice of the effects of a load increment ratio, duration of sustained loading and thickness of a clay. As a result, it can be concluded that the present theory is capable of explaining extensively the consolidation characteristics of aged clays.

DETERMINATION OF SOIL INDEXES

For the sake of establishing a method for estimating the consolidation of aged clays, it is necessary to find out procedures through which the soil indexes are determined. Among these, the indexes of compressibility C_{eq}, C_c and C_α, can be readily determined from ordinary consolidation tests and the coefficient of permeability k from permeability tests. However, the estimation of the quasi-preconsolidation pressure p_c' and the coefficient κ is not easy. Herein, the determination of these soil indexes will be considered, together with the examination of the characteristics of $R(t)$ or $S(t)$.

Quasi-preconsolidation Pressure p_c'

The quasi-preconsolidation pressure p_c' is misestimated on account of the release of stress and the disturbance of soil structure when sampling. Therefore, a reliable determination of p_c' from consolidation tests necessitates special techniques and procedures (Bjerrum, 1967). Bjerrum (1967) has recommended the use of vane tests from a practical point of view. Whichever method is used, it may be troublesome to determine p_c' of an in-situ aged clay. However, if the stress history of a clay is known and the drainage length of the clay is short, it is relatively easy to estimate p_c' of the clay. In the author's preceding paper (1979), the following expression has been derived on the basis of the Bjerrum concept:

$$p_c' = (t_1/t_0)^{C_\alpha/(C_c - C_{eq})}\, p_0'$$

where t_1=previous loading duration and t_0=time at which primary consolidation has just completed. In actual cases, p_c' may be greater about 1.1 times than that predicted from the above formula, because secondary consolidation occurs a little in the range of primary compression. Therefore, we have:

$$p_c' = \beta (t_1/t_0)^{C_\alpha/(C_c - C_{eq})} p_0' \qquad (\beta = 1.0 \sim 1.1)$$

Since the stress history of a specimen which is employed in a laboratory test is known in general, p_c' of the specimen can be estimated on the basis of the above formula. It should be, however, noted that the formula becomes more inaccurate as a clay mass is thicker, since the state path of a soil element which is distant from a permeable face deviates from that presumed by Bjerrum.

Coefficient κ

The coefficient κ is defined as the ratio of the rate of vertical strain to the rate of the decay of excess pore-water pressure induced within a clay under an undrained loading condition, and is thought to be constant within the clay. Therefore, κ can be indirectly determined, if the observations of vertical displacement and mid-plane pore-water pressure are performed in an undrained oedometer test. The tests have been actually conducted by employing a devised oedometer, which can control the drainage of pore-water from a specimen and permits no leakage under an undrained condition. Fig. 9 shows an example of the observations. In this case, the coefficient κ is evaluated to be 4.1×10^{-5} (m^2/kN), which is very large as compared with that of free pore-water ($\kappa = (4 \sim 5) \times 10^{-7}$ (m^2/kN)).

Rate of the Decay of Pore Pressure $R(t)$

The excess pore-water pressure may be separated into two components of u_p and u_f which are unaffected and affected by the interaction between adsorbed moisture and free pore-water respectively. Since the definition of $R(t)$ is such as described before, $R(t)$ can be then expressed as $R(t) = \partial u_f/\partial t = \partial u/\partial t - \partial u_p/\partial t$. At the early stage of consolidation, the rate of the change in u_p is very small within a clay except for the neighborhood of a permeable face. Therefore, $R(t)$ may be approximated by $\partial u/\partial t$. On the other hand, at the neighborhood of a permeable face, the effective pressure becomes greater than p_c' as soon as consolidation breaks out. In consequence, Eq. (1)′ is reduced to Eq. (1) immediately. The approximation of $R(t)$ has thus little influence upon the essential characteristics of consolidation. Accordingly, $S(t)$ is approximated by $\partial p'/\partial t$ as assumed before, if an applied pressure remains constant.

APPLICABILITY OF THEORY AND METHOD PROPOSED

The applicability of the present theory is quantitatively examined by comparing with the results of laboratory consolidation tests, which were conducted in a constant temperature room by employing an alluvial clay taken from Yokohama. Physical properties of the clay are given in Table 2. The de-aired slurried sample of clay was poured into a cell and consolidated to 39.2 (kN/m^2) under a series of small pressure increments, by taking care that loading duration became equal to the time of 100% primary consolidation. After the sample was left under the pressure of 39.2 (kN/m^2) for a certain period in the cell so as to be subjected to secondary compression, the test was conducted under the application of a prescribed pressure increment. The pore-water pressure and the transmitted soil pressure at the base of the sample were measured by transducers, and the volume change of sample by a dial-gauge. The used cells were 1(cm), 6(cm) and 10(cm) in height and 6(cm) in diameter, and permitted free drainage of pore-water from

Table 2. Physical properties of Yokohama clay

Specific gravity of soil particles	Liquid limit	Plastic limit	Per cent by weight <2 μm
2.70	94.5%	44.3%	16.0%

Table 3. Index properties of Yokohama clay and test conditions

(a)

Compression index; C_c	0.597
Quasi-compression index; C_{cq}	0.033
Coefficient of secondary compression; C_α	0.013
Coefficient of permeability; k	5.9×10^{-8}(cm/s)*
Coefficient of volume change; κ	$(0\sim5)\times10^{-5}$(m²/kN)
Initial void ratio; e_0	1.996*

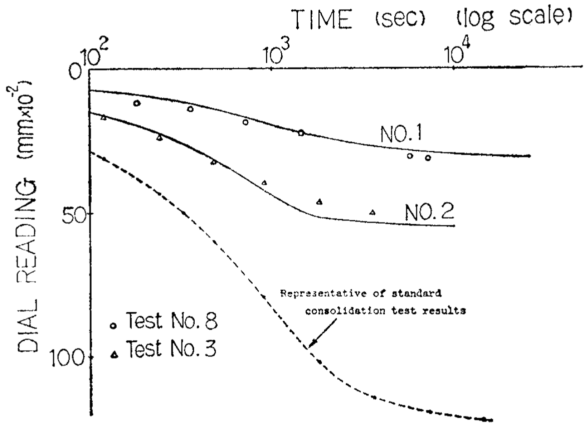
* values at $p'=39.2$(kN/m²)

(b)

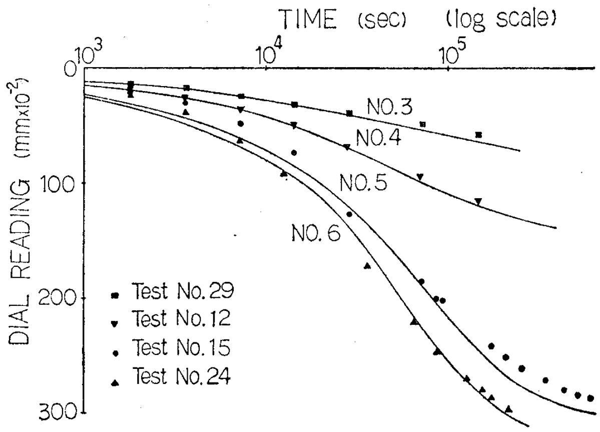
Predicted	Observed	H_0 (cm)	t_0(hours)	t_1(hours)	p_0' (kN/m²)	p_f' (kN/m²)	p_c' (kN/m²)	κ (m²/kN)
No. 1	Test No. 8	0.89	0.67	120.0	39.2	58.8	44.4	5×10^{-5}
No. 2	Test No. 3	0.89	0.67	1.0	39.2	78.4	39.7	0
No. 3	Test No. 29	5.53	27.0	60.0	39.2	44.1	40.5	4×10^{-5}
No. 4	Test No. 12	5.68	28.0	63.0	39.2	49.0	40.8	4×10^{-5}
No. 5	Test No. 15	9.17	71.0	120.0	39.2	58.8	41.7	4×10^{-5}
No. 6	Test No. 24	8.82	68.0	68.0	39.2	58.8	39.2	0
—	Standard test	1.95	—	24.0	39.2	78.4	—	—

the top of the sample only. The tests were intentionally carried out without the application of a back pressure.

By using soil indexes determined from preliminary tests including a standard consolidation test and an undrained loading test, it was examined whether the present theory could estimate the consolidation in the laboratory model tests with satisfactory accuracy. The soil indexes and the test conditions are shown in Table 3. The comparisons between the predicted and the observed results are presented in Figs. 10 and 11. For a variety of load increment ratios and duration of sustained loading, the predicted time-settlement curves are shown together with the observed values in Fig. 10. The time history of excess pore-water pressure at the base of sample is presented in Fig. 11. It can be found from these figures that the proposed theory gives a reliable estimate of the settlement-time histories of aged clays, and explains such a peculiar phenomenon as the development of excess pore-water pressure apparently less than an applied pressure increment or the rapid pore-water pressure dissipation at the early stage of consolidation. However,



(a)



(b)

Fig. 10. Comparison between predicted and observed consolidation settlements

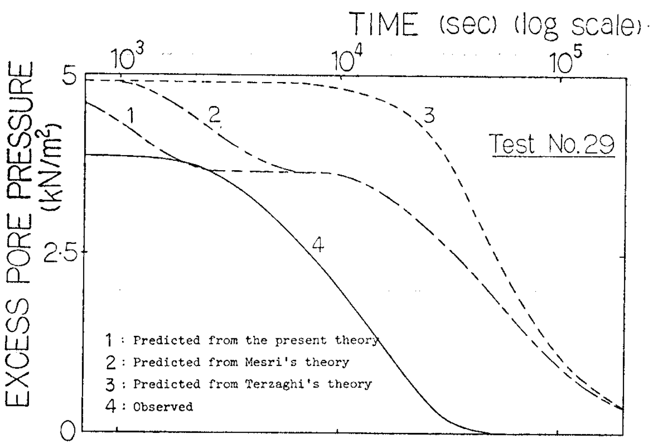


Fig. 11. Comparison between predicted and observed time histories of mid-plane pore-water pressure

the observed dissipation of excess pore-water pressure is considerably rapid compared with that predicted from the theories.

Thus, the applicability of the present theory has been examined by means of comparing with the results of consolidation tests in laboratory and it has been found that the proposed method for estimating consolidation, which is based upon Eq. (6) together with the soil indexes obtained from prescribed preliminary tests, is useful for an aged clay within which the maximum drainage length is relatively short. It is worth, however, noting that the acquirement of available field observations and the performance of consolidation tests on thicker specimens are indispensable for the sake of examining the applicability of the proposed theory to the consolidation of an actual clay layer. Moreover, in order to establish a method for estimating the consolidation more accurately, the determination of a quasi-preconsolidation pressure of an in-situ clay and of a state path which is followed during consolidation by a soil element distant from a permeable face should be further investigated in future.

CONCLUSION

A mathematical model of the one-dimensional consolidation of aged clays has been developed by considering the properties such as secondary compression and preconsolidation effects, and a method for estimating the consolidation has been proposed. By comparing with the results of consolidation tests in laboratory, it has been demonstrated that the reliabilities of the theory and the method are fairly satisfactory. The main findings concerning the consolidation of aged clays which have been obtained in the present study are as follows:

(1) The preconsolidation effect has serious influence on the consolidation characteristics of aged clays. It can be said that the influence of a load increment ratio on consolidation is essentially involved by the preconsolidation effect. It is therefore inferred that the consolidation characteristics of young clays ($p_0'=p_c'$) are not influenced by the magnitude of a load increment ratio.

(2) The scale effect of consolidation is partly ascribed to the development of secondary consolidation in the stage of primary compression.

(3) The peculiar behavior of excess pore-water pressure at the early stage of the consolidation of an aged clay seems to be caused by the agency of adsorbed moisture.

NOTATION

C_c=compression index
C_{cq}=quasi-compression index
C_α=coefficient of secondary compression
e=void ratio
e_0=initial void ratio

H_0=initial thickness of clay mass
k=coefficient of permeability
p'=effective pressure
p_c'=quasi-preconsolidation pressure
p_f'=final effective pressure
p_0'=initial effective pressure
$R(t)$=rate of the decay of pore-water pressure under an undrained loading condition
$S(t)$=rate of the increase in effective pressure under an undrained loading condition
t=elapsed time
t_0=time at which primary consolidation has just completed
t_1=previous loading duration
u=excess pore-water pressure
z=vertical coordinates
κ=a coefficient related to the compressibility of an aged clay
$\delta e^{(p)}$=change in void ratio due to primary consolidation
$\delta e^{(s)}$=change in void ratio due to secondary consolidation
Δp=pressure increment
γ_w=weight of water in unit volume

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