INITIAL RATE OF SECONDARY COMPRESSION IN PLANE STRAIN CONSOLIDATION ANALYSIS

Tokai University Student Member ○Hong Pisith
OHBA Co.Ltd. Regular Member Takahiro Yoshidomi
PEC Co.Ltd. Masaru Akaishi
Tokai University Regular Member Motohiro Sugiyama

1. INTRODUCTION

The start time of consolidation in the clay layer varies depending on the distance from the drainage surface. Therefore, it does not seem to assume that secondary compression at all locations within the clay layer occurs simultaneously after loading immediately[1]. Although secondary compression may occur depending on the distance from the drainage surface, secondary compression behavior during primary consolidation cannot be directly confirmed by the experiments. This paper examines the initial conditions required to evaluate the secondary compression under the plane strain condition by road embankment. It is shown that the assumption for the initial condition of secondary compression greatly affects the prediction of long-term consolidation settlement.

2. SECONDARY COMPRESSION MODEL

The rate of one-dimensional consolidation (= volume strain rate) is expressed by the Eq.(1) as the sum of the primary consolidation rate $\dot{\varepsilon}_p$, and the secondary compression rate $\dot{\varepsilon}_S$ expressed by the Eq.(2).

$$\dot{\varepsilon}(= m_v * \dot{\sigma}) = \dot{\varepsilon}_p(= m_p * \dot{\sigma}) + \dot{\varepsilon}_s \quad (1)$$

$$\dot{\varepsilon}_S = \dot{\varepsilon}_i * \exp(-\varepsilon_S/\alpha) \quad (2)$$

where m_v and m_p are the coefficient of volume compressibility defined by total settlement and primary consolidation, respectively, $\dot{\sigma}$ is the vertical effective stress rate, α is the coefficient of secondary compression, $\dot{\varepsilon}_i$ is the initial rate of secondary compression, t is time and the superscript "・" indicates as rate.

Using the coefficient of secondary compression α observed in the one-dimensional consolidation test and the total settlement one day after, $\dot{\varepsilon}_i$ is determined by Eq.(3) assuming the secondary compression ε_{sf} included in the total settlement. Therefore, $\dot{\varepsilon}_i$ determined by the proposed method depends on the maximum drainage distance of the one-dimensional consolidation test, the consolidation time, and the amount of consolidation at that time.

$$\dot{\varepsilon}_i = \dot{\varepsilon}_{sf} * \exp(\varepsilon_{sf}/\alpha) \quad (3)$$

where ε_{sf} is the amount of secondary compression at a certain consolidation time t_f after the end of primary consolidation, and $\dot{\varepsilon}_{sf} = \alpha/t_f$ is the rate of secondary compression at time t_f.

The consolidation equation of plane strain condition and sand drain in consideration of the secondary compression is expressed by Eq. (4).

$$\frac{\partial u}{\partial t} = c_v^* \frac{\partial^2 u}{\partial y^2} + c_h^* \frac{\partial^2 u}{\partial y^2} + \frac{\partial \sigma_y}{\partial t} + \dot{\varepsilon}_s/m_p \quad (4)$$

where c^*_v (= $k/(\gamma_\omega * m_p)$) is the coefficient of consolidation defined by primary consolidation, and $c^*_v = c^*_h = c_v$ are assumed.

3. EXPERIMENTAL RESULTS AND DISCUSSION

3.1 Results of 1-D Test and Soil Constants

The primary consolidation amount calculated by m_p/m_v =1 and α=0 is the red broken line in Fig. 1. The solid line with m_p/m_v=0.7 is the result of a trial calculations in which the primary consolidation amount was changed, and the consolidation time curve was determined to be close to the test result. The initial rate of the secondary compression is $\dot{\varepsilon}_i$=33.2 (1/day), but it should be noted that it is a value obtained from the test result of H=1 cm. However, soil constants in Table 1 are also used for the plane strain consolidation analysis.

Table 1 Soil constants for plane strain consolidation analysis

m_v (1/kPa)	c^*_v (=c^*_h) (cm²/min)	α	m_p / m_v	G (kPa)
1.26×10^{-3}	0.06	9.0×10^{-3}	0.7	9.0

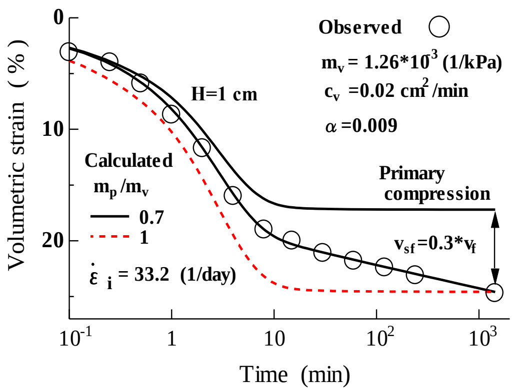

Fig.1 Consolidation time curve of 1-D test

Keywords: Secondary compression, Finite difference analysis, Plane strain condition, Rate of secondary compression
Contact address: Kitakaname 4-1-1, Hiratsuka-shi, Kanagawa, 259-1292, +81-463-58-1211, sugi@keyaki.cc.u-tokai.ac.jp

3.2 Comparison of Observation and Calculation Results

Using the embankment shape of the Hitachi test fill for Joban Expressway as shown in Fig. 2, a plane strain consolidation analysis was performed with a double drainage condition and a maximum vertical drainage distance of H_F =750 cm. A clay layer with a thickness of 15 m was divided into grid spaces of 1 m in each of the x and y directions, and the half width in the x direction is 45 m.

Fig. 3 shows the measured values, by the calculation results of Researcher D[2]) from the report of the finite element analysis study committee of the Geotechnical Society and the author's proposed method. In the sand drain construction area, consolidation has been promoted and long-term settlement behavior due to secondary compression can be observed. The slope of the settlement curve is close to the coefficient of secondary compression α used for the calculation.

In order to calculate the consolidation time curve of Hypothesis A, the consolidation settlement S_c shown by the blue solid line was calculated by $\dot{\varepsilon}_i$ = 33.2 of H_L = 1 cm by $(H_F / H_L)^2$ to 5.9 $\times 10^{-5}$ (1/day). The blue broken line in Fig. 3 is the total settlement S (= S_c + S_i) obtained by adding the immediate settlement S_i due to shear deformation to S_c. Although it is a simple calculation method based on the finite difference method assuming the shear elastic modulus G, it is recognized that the actual total settlement S may be predicted by assuming the immediate settlement S_i.

3.3 Effect of Initial Rate of Secondary Compression

Fig. 4 shows the consolidation time curve without immediate settlement S_i calculated by changing only the initial rate of secondary compression $\dot{\varepsilon}_i$. The consolidation amount increases by increasing $\dot{\varepsilon}_i$ by one digit. By adjusting $\dot{\varepsilon}_i$, it is also possible to calculate hypothesis B. Fig. 5 shows an example of the relationship between the one-dimensional consolidation settlement time curve and the setting $\dot{\varepsilon}_i$ of the sand drain placement ground. It is clearly understood that $\dot{\varepsilon}_i$ has a large effect on the predicted settlement as well as the analysis result of the nontreated ground.

4. CONCLUSIONS

The problems of applying the initial rate of secondary compression obtained from the one-dimensional consolidation test to plane strain conditions were investigated. Since the maximum drainage distance cannot be specified by plane strain (two-dimensional) consolidation, the initial rate of secondary compression set by the one-dimensional consolidation test with the maximum drainage distance of 1 cm cannot be used. The consolidation analysis of the sand drained ground does not correspond to the one-dimensional consolidation in drainage conditions. In the consolidation analysis including the secondary consolidation, it is necessary to pay attention that the prediction result greatly changes depending on the initial condition.

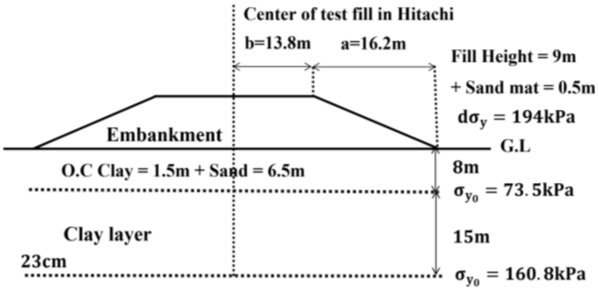

Fig.2 Cross section of clay layer and embankment

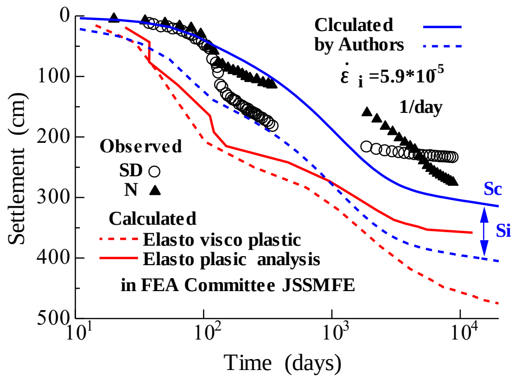

Fig.3 Settlement time curve of Kanda test embankment

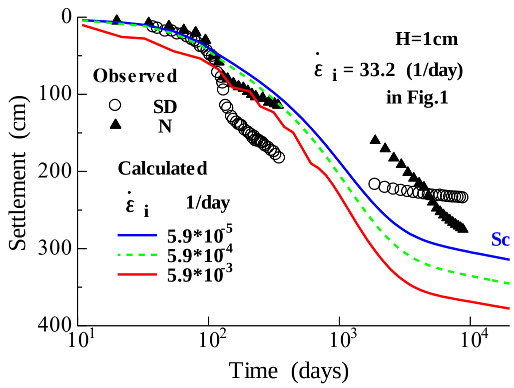

Fig.4 Assumption of initial rate of secondary compression for nontreated ground

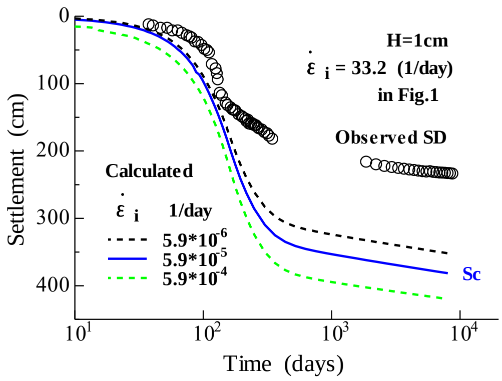

Fig.5 Assumption of initial rate of secondary compression for sand drain ground

REFERENCES

1) Suklje, L：Rheological aspect of soil mechanics, John Wiley and Sons, New York, 1969

2) Japan Geotechnical Society: "Application of FEM to Design in Geotechnical Engineering", Report on Research Committee Activities, 2005.