SOILS AND FOUNDATIONS Vol. 46, No. 2, Apr. 2006
Japanese Geotechnical Society

DISCUSSIONS

TWO CASE STUDIES OF CONSOLIDATION SETTLEMENT ANALYSIS USING CONSTANT RATE OF STRAIN CONSOLIDATION TEST[i]

Discussion by J.-C. CHAI[ii], N. MIURA[iii] and S. HAYASHI[iv]

The writers presented interesting field data and analysis results. On determining the consolidation parameters of prefabricated vertical drains (PVDs) improved subsoil, we would like to discuss the following two points.

SMEAR EFFECT AND WELL RESISTANCE

The writers stated that because the difficult on quantitatively evaluating the effect of the smear zone and the well resistance, an "apparent" value of the coefficient of consolidation in horizontal direction (c_h) was used. For both cases reported, the clay deposits were in an overconsolidated state and the maximum consolidation stresses were around the yielding stresses. Therefore, the value of the coefficient of consolidation in the horizontal direction at overconsolidation state ($c_{h(OC)}$) is an important parameter for simulating the consolidation process of PVDs improved subsoil. However, the ways to determine the "apparent" $c_{h(OC)}$ value were different for two case histories reported. For Yokohama site, Japan, the value of $c_{h(OC)}$ was assumed the same as the coefficient of consolidation in the vertical direction at normally consolidation state ($c_{v(NC)}$) ($c_{h(OC)}=c_{v(NC)}$). If the well resistance can be ignored, $c_{h(OC)}=c_{v(NC)}$ implies more smear effect. For Banjarmasin site, Indonesia, $c_{h(OC)}=c_{v(OC)}$ was assumed and it means less smear effect. The value of $c_{v(OC)}$ adopted was 40 times of $c_{v(NC)}$. The writers tentatively proposed that when $C_{v(NC)}/d_e^2>10^{-3}/d$ (d_e is the diameter of a unit cell) is satisfied, $c_{h(OC)}=c_{v(NC)}$ assumption can be adopted. As a tendency, the smaller the d_e value, the more significant the effect of the smear zone will be. However, there is no any fundamental base that a deposit has a larger $c_{v(NC)}$ value will tend to have more smear effect or well resistance. We agree that the parameters for the smear zone and the well resistance are normally not available from routing site investigation. However, the researches on the smear effect and the well resistance have been progressed and there are lots of reference data available. Referring the available data from the literature (Jamiolkowski and Lancellotta, 1981; Jamiolkowski et al., 1983; Hansbo, 1987; Holtz et al., 1991; Miura et al., 1993; Chai and Miura, 1999; Miura and Chai, 2000), Chai et al. (2001) proposed the following methods to evaluate the parameters of the smear zone and the well resistance.

(1) Discharge capacity of PVD (related to the well resistance). The discharge capacity (q_w) of PVD needs to be determined by long term confined in-clay test. If there are no test data available, $q_w \cong 100\ \mathrm{m^3/yr}$ is suggested. Generally, if the hydraulic conductivity of clayey deposit is low ($<10^{-8}$ m/s) and $q_w>100\ \mathrm{m^3/yr}$, q_w will not have a significant effect on the rate of consolidation.

(2) Smear-zone diameter. The smear zone diameter, d_s, can be estimated as:

$$d_s=3d_m \tag{8}$$

where d_m is the area equivalent diameter of a mandrel for installing PVDs.

(3) The ratio of k_h/k_s (k_h and k_s are the hydraulic conductivities of a natural deposit in the horizontal direction and the smear zone, respectively). The equation for evaluating the field value of $(k_h/k_s)_f$ is as follows:

$$\left(\frac{k_h}{k_s}\right)_f = C_f\cdot\left(\frac{k_h}{k_s}\right)_L \tag{9}$$

where C_f is the ratio of field hydraulic conductivity $(k_h)_f$ over corresponding laboratory value $(k_h)_L$. $(k_h/k_s)_L$ is the laboratory value of hydraulic conductivity ratio. The usefulness of the proposed method had been demonstrated by analyzing the field tests at Saga, Japan, Hangzhou, China and Bangkok, Thailand (Chai et al., 2001). The back-calculated $(k_h/k_s)_f$ values are about 10–15. The value of C_f will be discussed in the next section.

FIELD HYDRAULIC CONDUCTIVITY VERSUS LABORATORY HYDRAULIC CONDUCTIVITY

For clayey deposits, it is well known that laboratory tests generally underestimate the field values of hydraulic conductivity (Tavenas et al., 1986; Chai and Miura, 1999). This is because the sample used in laboratory consolidation test is typically 20 mm thick, which can not consider the effect of stratification (sand seams and sand lenses) of a natural deposit. Therefore, $C_f \geq 1.0$. For a homogeneous deposit, the C_f value can be close to 1.0, but for stratified deposits, even those with thin sand layers and sand seams which can not be clearly identified from the borehole record, the C_f value can be much larger than 1.0. The C_f values of a few clay deposits are listed in Table 3 for reference. Assuming that the compression index (C_c) is the same for the field and the laboratory, the ratio of the hydraulic conductivities can also be adopted

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Table 3. C_f value for a few clay deposits

Deposit	C_f value	Method for evaluation field of hydraulic conductivity	Remarks
Bangkok clay at Asian Institute of Technology campus	25	Back-analysis	Chai et al. (1995)
Bangkok clay at Nong Hao (close to sea)	4	Back-analysis	Chai et al. (1996)
Malaysia Muar clay deposit	2	Back-analysis	Chai and Bergado (1993)
Ariake clay (close to sea area)	4	Back-analysis	Chai and Miura (1999)
Clayey deposit in Eastern China	6	Back-analysis	Shen et al. (2000)
Louiseville (Canada)	About 1[a]	Self-boring permeameter	Tavenas et al. (1986)
St-Alban (Canada)	About 3[a]	Self-boring permeameter	Tavenas et al. (1986)

[a]Laboratory value was determined by direct measurement. For other cases, laboratory values were deduced from C_v value (C_v is coefficient of consolidation).

for the coefficients of consolidation. It is guessed that for the two cases reported by the writers, Yokohama site may have a smaller C_f value and Banjarmasin site may have a larger C_f value. This can be confirmed if the field test data of embankments on the natural deposits are available. If this is the case, the c_h values adopted in the analyses by the writers can be explained in a more rational way.

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TWO CASE STUDIES OF CONSOLIDATION SETTLEMENT ANALYSIS USING CONSTANT RATE OF STRAIN CONSOLIDATION TEST[i)]

Closure by KOJI SUZUKI[ii)] and KAZUYA YASUHARA[iii)]

The writers treated consolidation settlement started from overconsolided state. Therefore, consolidation in the two case studies presented in Figs. 15 and 19 can be divided into three phases.

Phase I (before PVD installation): the deposit is in overconsolidated state and consolidation is one dimensional.

Phase II (after PVD installation): the deposit is in overconsolidated state and consolidation includes radius drainage. From PVD installation to 450 days for Isogo case and 280 days for Banjarmasin case.

Phase III (after PVD installation): the deposit is in normally consolidated state and consolidation includes radius drainage. After 450 days for Isogo case and 280 days for Banjarmasin case.

The discussers pointed out two important aspects in prediction of consolidation with vertical drains. The first one is the effect of smeared zone and the second is the difference of permeability between laboratory specimens and actual deposits. These two aspects are studied in succeeding paragraphs for each phase by comparing the results of analysis and actual settlement behavior shown

i) Vol. 44, No. 6, December 2004, pp. 69–81. (Previous discussion by J.-C. Chai, N. Miura and S. Hayashi, Vol. 46, No. 2, April 2006, pp. 267–268).

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