

## EFFECTS OF FRICTION AND THICKNESS ON LONG-TERM CONSOLIDATION BEHAVIOR OF OSAKA BAY CLAYS<sup>i)</sup>

Closure by YOICHI WATABE<sup>ii)</sup>, KAORU UDAKA<sup>iii)</sup>,  
MASAKI KOBAYASHI<sup>iv)</sup>, TAKECHIHO TABATA<sup>v)</sup>  
and TSUYOSHI EMURA<sup>vi)</sup>

### INTRODUCTION

The authors would like to acknowledge the discussers for their interest in this technical paper. Many previous studies on the consolidation behavior of Osaka Bay clay, particularly those collected from the construction site of the Kansai International Airport, have been reported (e.g., Nakase, 1987; Tanaka and Locat, 1999; Akai, 2000; Imai et al., 2005; Tanaka, 2005a, 2005b). We believe that most of the previous studies are not denied by recent findings, comparing with our own test results.

The discussor stated that most of the previous studies explain the unsatisfactory settlement predictions by claiming that either well-established empirical concept is incorrect or not applicable to Osaka Bay clay. The authors understand that those previous studies did not have this kind of prejudice, and they reported the most recent findings at the time of writing. The authors have been studying not only Osaka Bay clay but also many other clays. Unfortunately we have never examined the clays which have been studied by the discussor; however, we have confirmed that the Osaka Bay clay is not a special one, and our findings from the Osaka Bay clay are applicable to the other clays as well. This fact will be published in the near future.

The main point of discussion is one of the most focused issues on the consolidation behavior, namely hypothesis A versus hypothesis B. The discussor concluded that the hypothesis A is correct because it is derived based on the discussor's empirical concept. On the other hand, as described in the first paragraph of the discussion, some of the findings on the Osaka Bay clay in the previous studies concluded to deny the hypothesis A. In our understanding, however, particularity of the Osaka Bay clay has not been conclusive in the previous studies. In the following section, we will discuss about the consolidation behavior of Osaka Bay clay based on our own test results.

### HYPOTHESIS A VERSUS HYPOTHESIS B IN THE PRESENT STUDY

In the conclusions of this paper, the authors stated that for clay samples without a developed structure, the strain

<sup>i)</sup> Vol. 48, No. 4, August 2008, pp. 547–561 (Previous discussion by G. Mesri, Vol. 49, No. 5, October 2009, 823–824.

<sup>ii)</sup> Port and Airport Research Institute, Japan (watabe@ipc.pari.go.jp).

<sup>iii)</sup> OYO Corporation, Japan.

<sup>iv)</sup> Coastal Development Institute of Technology, Japan.

<sup>v)</sup> Formerly Kansai International Airport Land Development Co., Ltd., Japan.

<sup>vi)</sup> Kansai International Airport Co., Ltd., Japan.

variation follows hypothesis A; however, for clay samples with a developed structure, the strain variation follows hypothesis B. Even in the latter case, when we compare specimens with larger thicknesses, the strain variations follow hypothesis A. Consequently, all consolidation behavior follows hypothesis A between the laboratory and field, because the prototype clay layer is very thick. This description supports the discussor's empirical concept. On the other hand, the authors also stated that for clay samples with a developed structure, the strain variation follows hypothesis B, because the thickness of laboratory specimen is very thin. In this discussion, the threshold between thin and thick is very important.

In Watabe et al. (2008), we successfully demonstrated the long-term consolidation behavior of Osaka Bay clay by introducing the isotache concept (Šuklje, 1957; Leroueil et al., 1985) which focuses on the strain rate effect relating to the viscosity. The isotache concept consequently supports hypothesis B. Therefore, from the author's basic empirical standpoint, we support hypothesis B for clay samples with a developed structure when the field consolidation behavior is estimated from the laboratory test result with a thickness of 20 mm with double-side drainage.

The key factor to understand this behavior is a "structure." Some of authors' test results supporting hypothesis A can be explained by re-structuring. Because strain rate in the test with a thickness of 100 mm with single-side drainage is significantly smaller than that in the test with a thickness of 20 mm with single-side drainage, the primary consolidation strain in the former becomes smaller than that in the latter due to re-structuring. The strain rate in the field is much smaller than that in the laboratory tests; therefore, the effect of re-structuring cannot be ignored. This fact indicates that the consolidation behavior in the field and the laboratory tends to follow hypothesis A. On the other hand, Osaka Bay clay named as Ma12 and Ma11 with a developed structure tended to follow hypothesis B. The compression curve for these samples shifted upward from that for those reconstituted samples, i.e., a smaller consolidation strain at the end of primary consolidation (EOP), because of a remaining structure even in the normal consolidation range as well as a large strain rate when the structure was suddenly breaking down.

Hypothesis A derived from the discussor's empirical concept is supported by major part of the test results in this paper. Hypothesis A is a practical and empirical rule

when re-structuring is significant, corresponding to a very small strain rate in the field. In addition, if the structured clay sample collected from the field is significantly disturbed, consolidation strain becomes larger, resulting in hypothesis A.

On the other hand, because isotache concept can generally demonstrate the long-term consolidation behavior for Osaka Bay clay, even with a developed structure, as shown in Watabe et al. (2008), the consolidation behavior generally results in hypothesis B. Particularly, if we deal with high-quality clay samples with a developed structure, hypothesis B is strongly supported.

## CLOSING REMARKS

The question that the consolidation behavior in the laboratory and the field follows the alternative of hypothesis A or B is a very important geotechnical issue, but it is not necessary to rush to conclusion. As abovementioned, hypothesis A derived from the discussor's empirical concept is supported by major part of the test results in this study. However, we have negative thinking about this to be regarded as a general rule. Because the isotache concept relating to the strain rate dependency can be generally applicable to a series of the long-term consolidation test results, hypothesis B is thought to be an essential rule rather than hypothesis A. Only in a case of either disturbed or significantly re-structured samples, hypothesis A is dominant rather than hypothesis B.

Based on our own experience, however, we have not reached decisive conclusion up to today. We will pursue this research further to find out the essential/general rule for the consolidation behavior, by accumulating high-quality laboratory tests and field observation data, with reference to the previous studies including the discussor's empirical concept.

## References

- 22) Leroueil, S., Kabbaj, M., Tavenas, F. and Bouchard, R. (1985): Stress-strain-strain rate relation for the compressibility of sensitive natural clays, *Géotechnique*, **35**(2), 159–180.
- 23) Šuklje, L. (1957): The analysis of the consolidation process by the isotache method, *Proc. 4th ICSMFE*, London, **1**, 200–206.
- 24) Watabe, Y., Udaka, K. and Morikawa, Y. (2008): Strain rate effect on long-term consolidation of Osaka Bay clay, *Soils and Foundations*, **48**(4), 495–509.