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Technical session 1f: Prediction and performance

Séances techniques 1f: Prédiction et performance

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1 INTRODUCTION

This paper presents a summary of the topics presented and discussed during Technical Session *"1f: Prediction and Performance."* The session members were as follows:

Chairman:	Prof. John P. Carter (Australia)
General Reporter:	Prof. David M.Potts (UK)
Panelists:	Prof. C.F. Leung (Singapore)
	Prof. B. Indraratna (Australia)
	Dr. M. Mimura (Japan)
	Prof. R.L. Michalowski (USA)
Session Secretary:	Dr. T. Kodaka (Japan)

Following the opening address by Chairman Prof. Carter, General reporter Prof. Potts presented a summary and short comment for each of the papers accepted this session. Four panelists then reported their research results related to *Prediction and Performance*. Floor discussion was opened following the panelist reports for the remainder of the session.

Photo 1. Chairman Prof. Carter and General reporter Prof. Potts

2 GENERAL REPORT

There are 33 papers allocated to this technical session representing 18 countries. The majority of these papers compare theoretical predictions with measurements made either in the laboratory or in the field. However, a few of the papers consider only theoretical predictions and some concetrate on the accuarcy of empirical relationships. They cover a wide range of geotechnical problems. The general reporter categorized all of the papers in terms of subject matter as listed in Table 1. For the details of the reviews for each paper, please see the general report for this technical session 1f included in this volume (Potts, 2006).
In the final remarks of his general report, the following discussion topics were identified:

1) Modelling of creep and secondary consolidation
2) The use of empirical equations for predicting settlements of soft clay
3) The limitations of the sub grade reaction method for analysing retaining walls
4) Appropriate constitutive models for use in Finite Element Analysis
5) Current status of using 3D numerical analysis
6) Deterministic versus probabilistic analysis

These discussion topics are real issues of *"Prediction and Performance"* in geotechnical engineering.

Table 1. Paper topics in Technical Session 1f categorized by the general reporter Prof. Potts

Geotechnical Problems			
Settlements on soft clay	Laboratory based research	(2)	13
	Analytical solutions	(1)	
	Numerical analysis	(2)	
	Empirical approaches	(8)	
Foundations	Shallow foundations	(5)	7
	Deep foundations	(2)	
Embankment dams			2
Retaining walls			6
Neural networks			2
Slope stability			1
Tunnels			1
Partially saturated soils			1
Number of papers			33

3 PANELIST REPORTS

3.1 *Prediction versus performance of a land reclamation bund by Prof. C.F. Leung*

Prof. Leung highlighted that despite a relatively high factor of safety of 1.5 against global slope stability being adopted in the design of bund, occasionally bund failures have been reported during bund construction in Singapore (*see*, Fig.1). Parametric studies have been carried out to evaluate the various factors that affect the performance of a bund and to identify the risks these factors pose to the bund stability. Finite element analysis was performed to investigate the soil displacements and to identify the soil yield zones. It has been established that the accurate alignment of the bund in relation to the sand compaction pile reinforced foundation is a critical factor especially when the bund under construction has a curved alignment. However, such a factor is not enough to cause the bund failure which is generally due to a combination of factors such as variations in the bund alignment, thickness and strength of soft soil and other factors (see, Fig.2). It is recommended that site investigation and soil tests must be properly carried out prior to design to identify potential problems during bund construction. During the presentation, Prof. Leung also identified several key issues for subsequent discussions and exchange of ideas. These issues included the identification of risks in geotechnical design, the importance of sound site investigation and additional considerations for non-standard situations such as curved bund alignment.

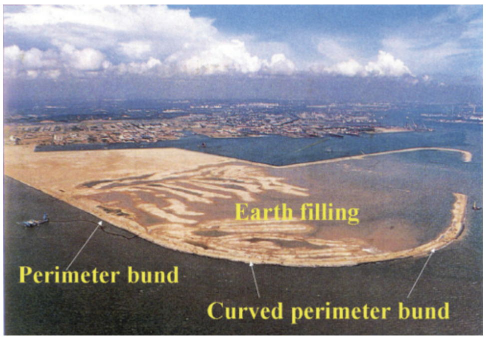

Figure 1. Large reclamation project in Singapore

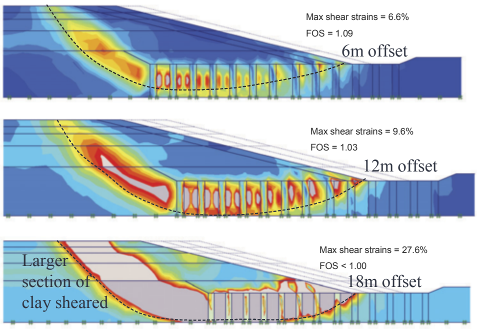

Figure 2. Failure pattern changed with bund offsets (Leung et al., 2006)

3.2 *Predictions vs Performance of Soft Clay Foundations improved by Vertical Drains by Prof. B. Indraratna*

In this presentation, the most important aspects of soft clay properties were first presented with details of parameters that are both convenient and difficult to determine accurately. The relevance of knowing the correct pre-consolidation pressure, the disadvantages of using reconstituted soils in the laboratory, the importance of evaluating the correct lateral permeability, the disturbance caused by mandrel driven prefabricated vertical drains and associated change in properties was discussed in the context of predicting the soft clay behaviour upon multi-stage embankment loading.

Soft clay foundation behaviour was compared with and without drains, and the challenges of Class A predictions based on simple analysis and numerical modelling were contrasted with available field data. Complexities introduced by extra parameters in certain constitutive models and non-linear flow assumptions in soil-drain interfaces do not always give better predictions. Case histories where simple analyses can give better predictions were also presented. Field evidence from Southeast Asia where pore pressures have not dissipated sufficiently even after several months in spite of vertical drains was presented, which lead to the interesting discussion of possible reasons for this observation (*see*, Fig.3). The aspects of drain clogging, piezometer tip malfunctioning, excessive smear effects and large lateral visco-plastic strains among other reasons were highlighted.

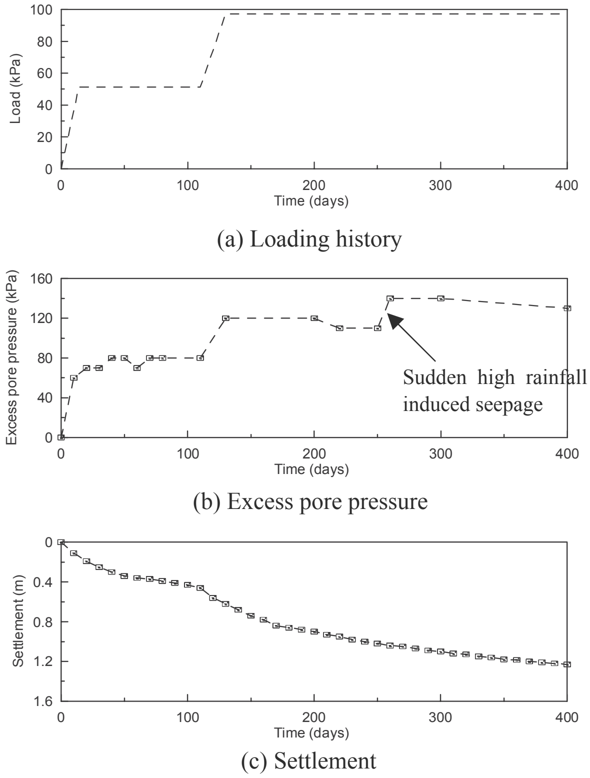

Figure 3. Case history of a clay embankment in Malaysia (Indranatna et al., 1994)

In the conclusions, the need for identifying and estimating accurately the most important soil properties, the need for most appropriate modelling of the soil-drain interface, consideration of the correct stress path history at various locations beneath the embankments, and the appropriate choice of constitutive model without unnecessary complexities were elucidated.

3.3 *Considerable factors to predict deformation of soft foundations by numerical analysis by Dr. M. Mimura*

Long-term settlement has occurred at the reclaimed area and islands in Osaka Bay (*see*, Fig.4) caused by the time-dependent compression of the Pleistocene clays. A new procedure to assess the compression characteristics of the Pleistocene clays in Osaka Bay has been proposed by considering the viscoplastic deformation in the quasi-overconsolidated region. The assumption that the time-dependent irreversible deformation occurs even in the region less than p_c as well as normally consolidation region is adopted for the proposed compression procedure based on the fact that the quasi-overconsolidated clays in Osaka Bay can be regarded as normally consolidated from the history of sedimentation environment. A series of one-dimensional

Figure 4. View of Osaka Port

elasto-viscoplastic finite element analyses in terms of the prescribed new procedure is carried out to evaluate the long-term settlement for Sakishima, Maishima and Yumeshima Reclaimed Islands in Osaka Port. On the basis of the calculated performance, the predictive accuracy of the proposed compression model for the quasi-overconsolidated Pleistocene clays in Osaka Port is discussed.

The calculated performance by the elasto-viscoplastic FE analyses formulated with the proposed procedure is found to successfully describe the in-situ long-term settlement of the Pleistocene deposits measured in the reclaimed islands in Osaka Bay, whereas the conventional framework did not function well (*see*, Fig.5). It is also confirmed that the estimation of G_0 for the Pleistocene gravelly sand deposits play a significant role for the settlement prediction especially during the early reclamation stage, and the adopted values of G_0 for the firm Pleistocene gravelly sand layers in the present analysis are trustworthy for describing the in-situ compression of the Pleistocene deposits.

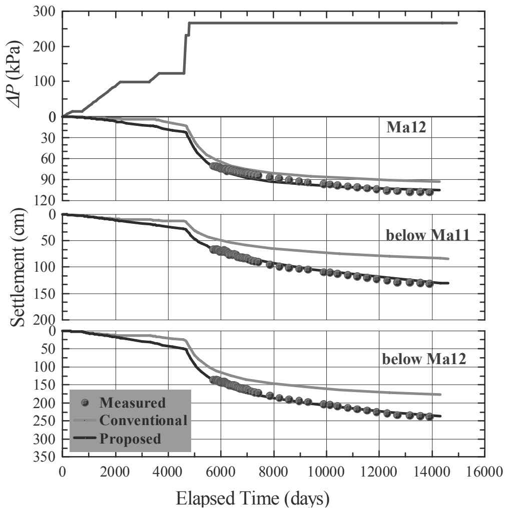

Figure 5. Predicted settlement for Sakishima Reclaimed Island (Mimura et al. 2005)

The question from the floor is as follows: According to the measured data, the settlement of Yumeshima reclaimed Pleistocene deposit looks almost terminated although the duration of consolidation is not enough. Please explain the reason of that together with what happens to the calculated performance.
Answer: Long-term interpretation is required to discuss the tendency of the settlement. Even if the advance in settlement looks terminated in a short period, it often begins to start. Of course the calculated performance exhibits steady gain in settlement with time.

3.4 *Predictions of heave in frost-susceptible soils by Prof. R. L. Michalowski*

Predictions of frost heave are part of forecasting the behavior of structures in regions of seasonal freezing, or in the permafrost regions subjected to seasonal thawing. Three necessary components of any successful predictions are: (a) understanding of the underlying physical processes, (b) construction of a mathematical model that reflects the physical process, and (c) implementation of the model in a (typically) numerical method and solving the boundary value problem with the appropriate boundary and initial conditions. A physical background of the frost heave process was first discussed, and then a new constitutive model describing this process was presented. Individual ice lenses are not simulated in this model; rather, the macroscopic deformation due to ice lensing is modeled by introducing a porosity growth tensor. The constitutive model was calibrated using available ramped freezing test results, and a step-freezing process was used to validate the model.

The model has been used to predict displacement of a retaining wall with frost-susceptible backfill. As the freezing front penetrates the backfill, the frost heave is manifested by substantial vertical displacements. However, as the freezing front passes through the wall, horizontal displacements become distinct, causing rotation of the retaining wall. The performance of the retaining wall can be improved, however, if the freezing front is prevented from moving far inside the backfill. This can be achieved by placing thermal insulation behind the retaining wall. Repeated simulation of freezing of the backfill, this time behind an insulated retaining wall, revealed a reduction in the wall's tilt (see, Fig.6).

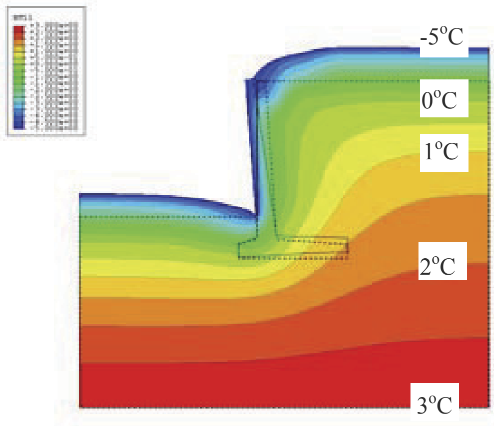

Figure 6. Predictions of heave in frost-susceptible soils (Michalowski, 2006)

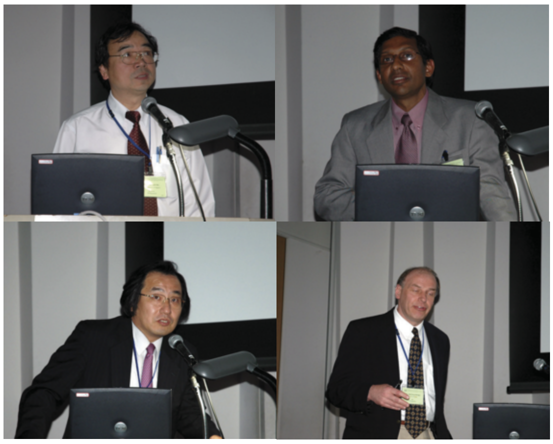

Photo 2. Panelists: Prof. Leung (Upper left), Dr. Indraratna (Upper right), Dr. Mimura (lower left), and Prof. Michalowski (lower right)

The predictions presented are theoretical in nature as the measurements of frost heave-caused displacements of structures with well-defined thermal initial and boundary conditions were not available to the author. However, the model appears to capture the frost heave effects rather well, and it is expected to be a valuable tool for predicting behavior of structures in cold regions.

4 DISCUSSIONS AND REMARKS

Active floor discussion following the panellist reports were opened by the Chairman Prof. Carter. Of the discussion topics suggested by the General reporter Prof. Potts, most of the discussions were focused on the first topic 'creep' behaviour of clay. From a practical point of view, it is difficult to determine the parameters for FEM even when a simplified constitutive model is used. In order to fit the predicted settlements and deformations to the actual measurement of soft ground, it is required to manipulate the parameters obtained in the laboratory and/or field tests. However, it should be noted that the most important issue for geotechnical engineers is to understand the physical modelling of soil behaviour and to use appropriate mathematical modelling. Performance prediction methods do not only fit the field data, but also strike us the complex behaviour of soil in terms of physical modelling.

Much interest was also generated in the reliability of field measurements, where and how they are measured as well as soil disturbance associated with instrumentation. For instance, the discussions related to the retarded pore pressure dissipation sometimes observed in the field is due to instrumentation malfunctioning, soil disturbance caused around the measurement location or whether this is due to true soil behaviour could not be concluded, even though high visco-plastic strains as a possible contributing factor was generally accepted.

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