Panel discussion: Interplay between physical and numerical models for soil-structural interaction problems

Débat de spécialistes: Interaction entre modèles physiques et modèles numériques pour résoudre les problèmes d'interaction sol-structure

C. F. Leung – *Centre for Soft Ground Engineering, Department of Civil Engineering, National University of Singapore, Singapore*

ABSTRACT: This discussion provides an insight on the role of interplay between physical and numerical models for soil-structural interaction problems. The relevant points are illustrated using the results of studies on deep excavation in soft clay and gravity caisson on sand.

1 INTRODUCTION

Two studies are used to illustrate the role of interplay between physical and numerical models for soil-structural interaction problems. The first study concerns soil movement due to deep excavation in soft clay which is a soil unloading problem. The second concerns displacement of gravity caisson on sand which is a soil loading problem.

2 DEEP EXCAVATION IN SOFT CLAY

Deep basement construction often takes place in heavily populated cities and soil movement is a major concern for deep excavation carried out in soft clay. For the present state of the art, there are generally large discrepancies between the measured and predicted soil movements behind the retaining wall of a deep excavation. A series of centrifuge model tests has been carried out at the National University of Singapore to evaluate the soil movements of deep excavation carried out in thick deposit of soft marine clay overlying stiff clay. The experimental setup and instrumentation to monitor the soil movement and pore pressure are shown in Fig. 1. In conjunction with the model study, finite element analysis (FEM) is carried out using the CRItical State finite element Program (CRISP) to back-analyse the test data using the modified Cam-Clay model. The parameters used in the FEM are obtained from triaxial compression and oedometer consolidation tests on the marine clay and stiff clay specimens prepared under identical stress conditions. Details of the test results and back analyses are given in Wei (1997).

Though the pore pressure can be predicted reasonably well by FEM, there are discrepancies between the measured and predicted ground surface settlements as shown in Fig. 2. In general, the FEM under-predicts the settlement closer to the retaining wall and grossly over-predicts the settlement further away from the wall. To evaluate the discrepancies, further FEM analyses were carried out by varying the boundary conditions at the retaining wall and at the end wall of the model container. A comparison between the measured ground surface settlements and FEM predicted results under different simulation conditions is shown in Fig. 3. By introducing appropriate interface slip elements at the retaining wall, the predicted ground settlements close to the wall agree well with the measured settlement. By introducing different roller conditions (either fixed or free end) at the end wall of the model container, the surface settlement due to container boundary effect can be investigated. For the ground surface settlements further away from the wall, the FEM results still over-predict the settlements even taking the container boundary effects into account. It is believed that the small strain effect is a major factor for the discrepancies. This is in line with the presentation made earlier by Professor R N Taylor of City University on his study on soil movements, see for example Stallebrass and Taylor (1997).

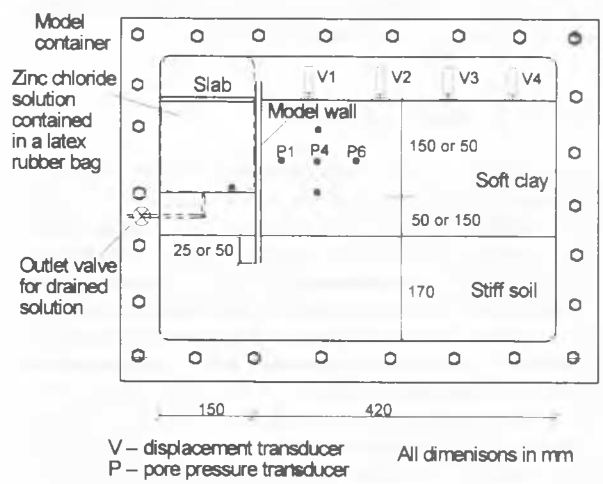

Fig. 1 Centrifuge model setup for deep excavation study

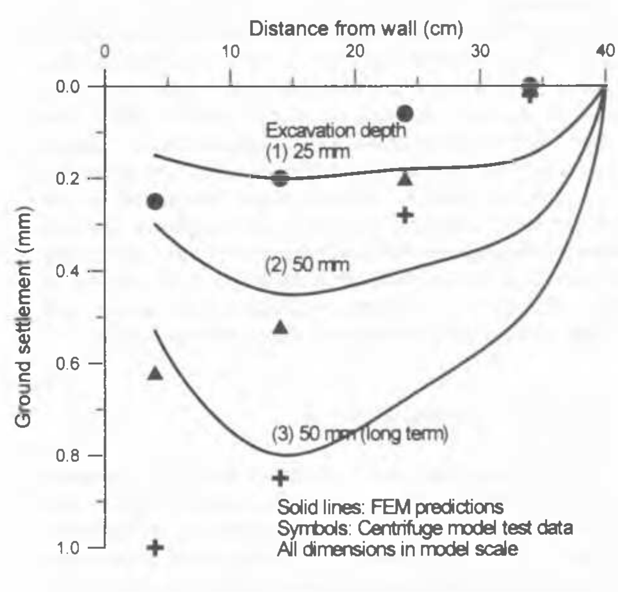

Fig. 2 Comparison of FEM and model ground settlements

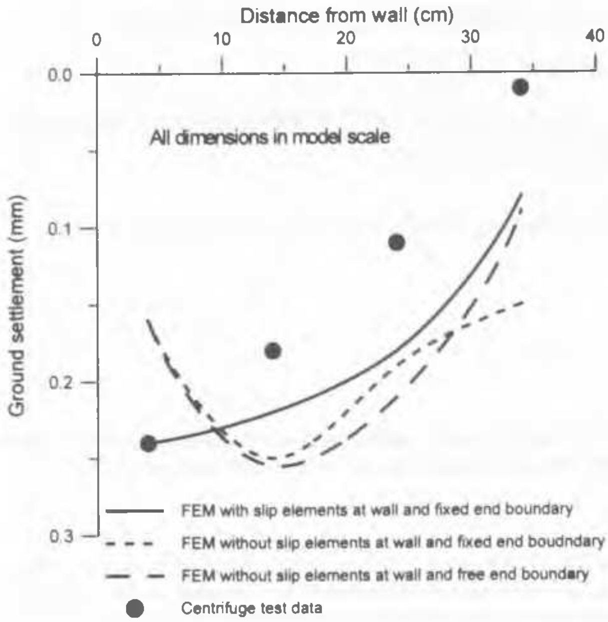

Fig. 3 Effects of interface at wall and container boundary conditions on surface settlement profile

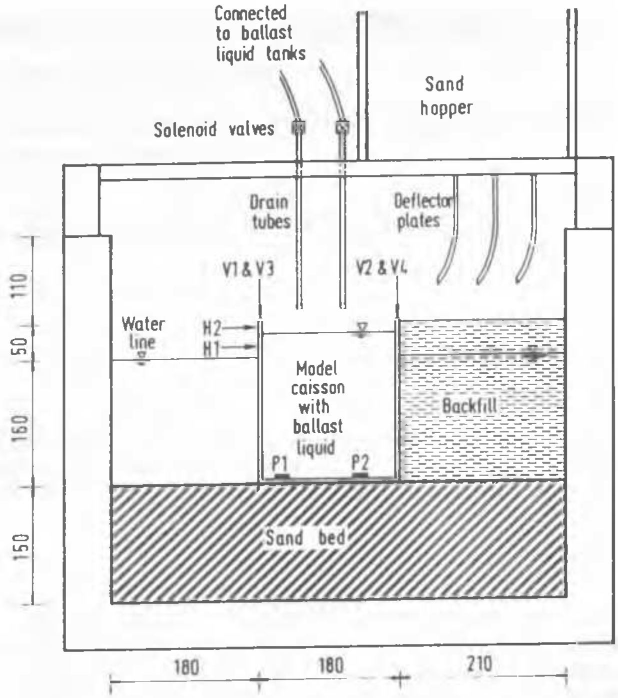

Fig. 4 Centrifuge model setup for gravity caisson

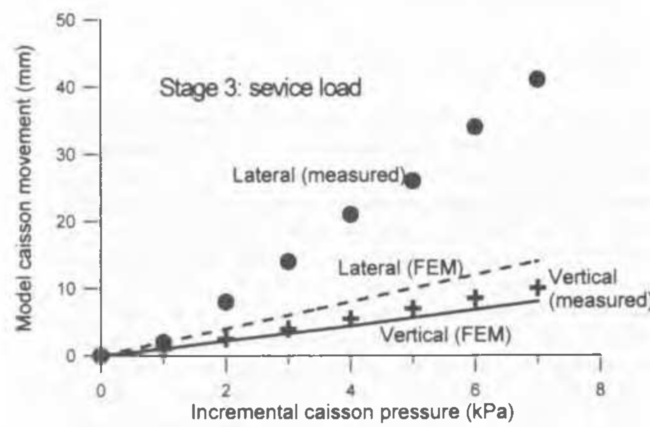

Fig. 5 Comparison of FEM and model test data

3 GRAVITY CAISSON ON SAND

Gravity caisson is a rigid retaining structure which is used as a wharf front structure for Singapore's New Container Terminal. Due to operation criteria of the quay crane on the caisson under service loading condition, stringent limits of vertical and horizontal caisson movements and tilting have been set by the mechanical engineers. A series of centrifuge model tests has been carried out at the National University of Singapore to examine the movements of gravity caisson supported on sand. A sketch of the experimental setup and instrument are shown in Fig. 4. The vertical movements of the caisson under three stages of loadings: (1) caisson sunk-in during installation (2) placement of backfill behind caisson and (3) under service load are investigated. In practice, the most critical case is stage (3) in which the caisson movements should lie within the limits set for the port operation. Details of the test results are presented in Leung et al. (1997).

In conjunction with the model study, a FEM is also carried out using the CRISP computer program to back analyse the model test results. The parameters used in the FEM are obtained from oedometer consolidation and shear box tests on the same sand. Details of the back analyses are given in Khoo (1994). The predicted caisson movements obtained using the Mohr-Coulomb soil model as compared to the measured values are shown in Fig. 5. It is evident that the vertical caisson movements can be predicted fairly accurately while there are large discrepancies between measured and predicted horizontal caisson movements and tilts. It is believed that this is attributed to the inability to model correctly the stress-strain response of the concrete/sand interface at the caisson base due to lack of experimental data.

4 CONCLUDING REMARKS

Two studies have been used to illustrate the role of interplay between physical and numerical models for the study of soil-structural interaction problems. By examining the discrepancies between the measured values from the physical models and predicted values from the numerical models, a much better understanding on the problems understudy can be gained.

Limitations of numerical models involving the small strain phenomenon and the interface stress-strain response are highlighted. A thorough investigation of such limitations would enable further interplay between physical and numerical models to achieve fine-tuning of the numerical models resulting in a better displacement predictions of a soil-structural interaction problem.

REFERENCES

Khoo, E. 1994. Behaviour of gravity caisson on sand. M Eng thesis, National University of Singapore.

Leung, C.F., F.H. Lee & E. Khoo 1997. Behaviour of gravity caisson on sand. *J. of Geotech. & Geoenviron. Engr.*, ASCE, 123: 187-196.

Stallebrass, S.E. & R.N. Taylor 1997. The development and evaluation of a constitutive model for prediction of ground movements in overconsolidated clay, *Geotechnique*, 47:235-254.

Wei, J. 1997. Centrifuge modelling of deep excavations. M Eng thesis submitted for examination, National University of Singapore.