Proceedings of the 16th International Conference on Soil Mechanics and Geotechnical Engineering

doi:10.3233/978-1-61499-656-9-3177

Technical session 2c: Excavation, retaining structures and foundations

Séances techniques 2c: Excavation, constructions de rétention et foundations

C.D. Ou - *Taipei City, Taiwan*
C.W.W. Ng - *The Hong Kong University of Science and Technology, Hong Kong*
M.D. Bolton - *University of Cambridge, UK*
J. Takemura - *Tokyo Institute of Technology, Japan*
I. Vanicek - *Czech Technical University in Prague, Czech Republic*
S. Wheeler - *University of Glasgow, UK*
K. Komiya - *Chiba Institute of Technology, Japan*

1 INTRODUCTION

Technical Session 2c (Excavation, Retaining Structures and Foundations) started at 3:30pm 12 September Monday. At first, *Dr. Chin-Der Ou* served his opening address to the General Assembly as the Chairperson of TS 2c. In TS 2c, 34 papers were presented from 16 countries and 2 regions (i.e., Hong Kong and Taiwan). 32 papers were in English and 2 papers were in French. One General Reporter and four Panellists were invited in this session.

2 THE GENERAL REPORT

The General Report was presented by *Prof. Charles W.W. Ng*. Prof. Ng summarized highlights the objectives, methodology and key findings of some selected papers only (but all papers in written version of General Report), raise questions/concerns and concluding remarks in his presentation. He classified 34 papers under four possible sub-themes, i.e., Excavation (9 papers), Retaining structures (6 papers), Shallow foundations (9 papers) and Deep foundations (10 papers). In each sub-theme, he took up following papers.

Excavation:
(i) Jet grout application for excavation in soft marine clay (His & Yu, Australia)
(ii) Design and numerical investigations of a deep excavation for a tunnel entrance pit (Raithel, Gebreselassie, Muller & Pahl, Germany)
(iii) Back analyses and safety prediction for an extremely deep foundation pit during its excavation (Song Lou & Lu, China)

In this sub-theme, he put forward problems about "The Missing Link in Numerical Design Analysis" and he advanced the point which needs clarifying, eg., "Calibrate Against Case Histories only, Enough ???"

Retaining structures
(i) Pile-Soil-Wall-Interaction during the construction process of deep excavation pits (Katzenbach, Bachmann & Gutberlet, Germany)
(ii) Modelling of horizontal earth pressures on retaining walls (Chua and Bolton, UK)
(iii) A simplified procedure to evaluate earthquake- induced displacement of gravity type retaining walls (Koseki, Japan)

Shallow Foundation
(i) The effectiveness of buried mass concrete thrust blocks as a means of lateral support for excavations (Goodey, McNamara, Taylor, UK)
(ii) Novel centrifuge simulations of restoration of building tilt (Ng, Lee, Xu & Zhou, Hong Kong SAR)
(iii) Continuum approach for analysis of short composite caisson foundation (Ali Jawaid & Madhav, India)
(iv) Densification of hydraulic fills by vibroflotation technique (Mecsi, Gokalp & Duzceer, Hungary /Turkey)

Deep Foundation
(i) Foundation engineering for the UK's new national stadium at Wembley (O'Brien, Hardy, Farooq & Ellis, UK)
(ii) Foundation design for a new cable-stayed bridge crossing the Panama Canal (Moormann & Humpf, Germany)
(iii) Mechanical behaviour of caisson foundation reinforced by steel pipe sheets piles (Isobe & Kimura, Japan)

The concluding remarks of his General Report was as follows;

- Some very interesting and excellent design case histories and results of field monitoring
- Comparisons of Class-A predictions and corresponding field measurements by some authors should be applauded. More Class-A predictions are needed.
- Interface elements are commonly used in design numerical analyses. How to assess input parameters?
- It is evident that more and more advanced in-flight construction simulation tools and novel modelling techniques such as the 4-axis robotic manipulator, the inclined loading device and the expanding tool are used to investigate various geotechnical problems in centrifuge model tests.
- High quality centrifuge data are presented in many papers. Not only the test data can assist us to improve our understanding of the mechanisms involved but also they are essential for calibrating constitutive soil models and numerical modelling procedures. Provide the missing link for Class-A design predictions.
- Fundamental differences between drained and undrained analyses are not properly discussed and modelled in some papers. Distinctions between effective stress and total stress analyses together with appropriate model parameters are not correctly differentiated and adopted. Ground water table is not defined in some FE analyses.
- Without proper explanations and justifications of input parameters, good " matches" between measured values and back-analysed results (i.e., Class-C predictions) are reported. These good "matches", however, have very limited scientific values.

3 PANEL PRESENTATIONS

In this session, four panellists conducted panel presentation.

Prof. Malcolm D. Bolton gave the presentation which focused on "Quick and accurate method to predict ground movements around braced excavations". At first he showed the aim of his presentation.

- Single calculation to verify safety and serviceability.
- Mobilisable Strength Design (MSD) is offered as an improvement to Limit State Design (LSD) in that it deals properly with serviceability.
- Limit equilibrium" plus compatibility.
- Direct non-linear ground displacement calculation based on a bare minimum of soil element data, without using constitutive equations or FEA.
- Focus: displacements caused by excavation in clay.
- He will show FEA plus three field examples as validation.
- He subsequently explained in detail about Limit equilibrium stability calculations, plastic deformation mechanisms, calculating strength mobilisation factor β, deriving structural distortion Δ and measured and predicted results for five sites. And he drew the conclusions as follows;
- Geo-structural plastic deformation mechanisms and MSD work well for stiff excavation support systems in undrained clays.
- One DSS stress-strain test (or, allowing for anisotropy, a triaxial or pressuremeter test) can be scaled to predict ground and wall movements $\pm$20%, as well as stability.
- System flexibility is allowed for only approximately ? FEA can be used to derive correction factors, following Clough & O'Rourke (1990) and Osman & Bolton (2004).
- Needs to be extended to the consolidation phase of clays, and to sands (if possible).

Dr. Jiro Takemura made the presentation titled "Centrifuge model tests on deep excavation in soft clay and its class A prediction". He presented about typical behaviour observed in the centrifuge, critical parameters or factors in the prediction before and after event, predictability and limitations in the prediction based on his research findings. He concluded this summary of;

- Centrifuge model with in-flight excavator can provide useful information on soil structure interaction of excavation in soft soils.
  - Key factors: construction sequence, stiffness of sand
- Prediction methods commonly used in design:
  - Accuracy of prediction before event might not be high.
  - Accuracy of prediction after event could not be satisfactorily high if the number of valuables back-calculated is limited.
  - They can not properly predict the effect of construction sequence, e.s. when the non-linearity is dominant in the deformation.

Prof. Ivan Vanicek gave the presentation titled "Limit state approach and design of spread foundations". He has contributed the summary of his presentation to this report as follows;

Panel Report of Ivan Vanicek "Limit state approach and design of spread foundation" pointed out that this approach is step forward, because potential risk of foundation design can be defined with a certain probability. His presentation was based on the long term experience with this approach for the design of spread foundations in the Czech Republic and also on the fact that Eurocode 7 Geotechnical Design which accepted limit state design is valid now in Europe. Risk probability in the Czech Republic was based on the assumption that 1 failure is acceptable in 10,000 cases. In fact during last 18 years, where this Czech code is used, no significant failure was observed and described. So probably the partial factors of safety are still the conservative values and can lowered.

In accordance with the recommendation of EC7 the following 5 questions was recommended for the discussion.

Classical approach using total factor of safety was recommended for bearing capacity for clays and undrained conditions in the range of 2.3 - 2.6, e.g. according to Hansen. EC 7 recommends partial factor for material properties, undrained cohesion γ_{cu} =1.4 which means that the total factor of safety is close to this value. Panelist therefore asked the audience if there is any justification that from now the overall factor of safety can be much lower. Will not this fact induce lower estimations of the characteristic values of undrained cohesion cu by geotechnical engineers? On the other side he admitted that in the Czech code the partial factor for cu was up to now 2.0 and no failure was observed, so the value of partial factor in the range of 1.8 and 1.6 would be more acceptable.

For other cases of bearing capacity where the angle of friction is not zero, this capacity strongly depends on the factors of bearing capacity which are directly functions of ψ. Reporter recommended to start the discussion whether partial factor for material (for j) can be for this case applied directly on ψ or on tanψ and if this factor have to be constant of progressive.

Another question is connected with accuracy by which we are able to determine the shear strength parameters, effective angle of internal friction and cohesion. Very often we suppose that the variability of cohesion is higher than for angle of friction, but EC 7 in the last version recommended the same partial factors 1.25.

When calculating bearing capacity with the help of overall stability, e.g. for subsoil reinforced by geosynthetics it was shown, that the result depends not only on the selected method of slope stability calculation but also on the assumption by which the influence of these reinforcing elements are taken into consideration. Reporter therefore expressed belief that the additional partial factor (e.g. 1.1) covering the influence of the calculation method have to be taken into account as well as partial factor covering higher risk for significant structures (e.g. 1.1 - 1.2), the failure of which can be the cause of very high damages.

Last question was connected with limit state of serviceability - settlement analysis for spread foundation, especially when stress-strain calculation method is used. Classical method is usually giving higher settlement than after that measured. EC 7 recommends stopping with individual layers settlement calculation in the depth where load increase is equal to 20% of the original vertical stresses. Czech code recommends to calculate the settlement of individual layers only from load increase lowered by a certain percentage of original vertical stresses, ranging between 10-50% ($m \cdot \sigma_{or}$, where m - structural strength parameter is in the range of 0.1 to 0.5 for different types of soils) expressing by this way the fact that the additional loading not exceeding this value is giving nearly negligible deformation. Recommended values of structural strength parameter were determined by in situ precise vertical deformation measurement under the real foundations. Question 5 therefore was "What is your experience in the field of determination of total settlement which is very close to the measured one?"

At the end of presentation it was expressed that 3 years of testing of EC7 especially in Europe will help to better understanding of the limit state approach.

Reaction from the floor was connected with inquiry for closer clarification of the settlement method using structural strength parameter.

Prof. Simon Wheeler presented about "Design and analysis of shallow foundations on unsaturated soils". He showed design issues of shallow foundation, stress state variables and volume change behaviour during isotropic or 1-D loading in detail, and he drew some Issues to consider as follows;

・ Consider worst case scenarios for absolute and differential displacements

・ Heavily loaded foundation elements may settle on wetting (collapse compression of underlying soil) whereas lightly loaded elements heave (swelling of underlying soil)

・ Consider whether wetting occurs from above or from below (or from the side), because the maximum absolute or differential displacement may occur at some intermediate stage of wetting if:

- some soil layers swell whereas others collapse
- individual layers swell then collapse or collapse then swell
- Wetting from the side means that wetting beneath different foundation elements occurs at different rates

He concluded his presentation that improved understanding of the mechanical behaviour of unsaturated soils, achieved over several decades, means that rational and relatively straightforward calculation procedures are now available for predicting displacements of shallow foundations constructed on unsaturated soils including movements caused by wetting and drying.

4 DISCUSSION TOPICS

The Discussion Topics provided by four Panellists were as follows;

Malcolm Bolton

(1) NOT: "Does my 20-parameter constitutive model, plus my FE package, ground profile and database of element testing, offer reasonable back-analyses of ground movements in completed works when I have tuned the parameter values accordingly?"

(2) INSTEAD: "What single stress-strain test on natural soil at the site of a future construction would add most value to the current design process to limit structural distortion whilst economising on the foundations?"

(3) AND: "How can the designer use this stress-strain data?"

Jiro Takemura

(4) Typical behaviour observed in the centrifuge?

(5) Critical parameters or factors in the prediction before and after event?

(6) Predictability and limitations in the prediction before event (prediction A)?

Ivan Vanicek

(7) Is there any justification that from now on the overall factor of safety in the range of 2.3-2.6 can become a much lower value? (only a little bit higher than 1.4 because EC 7 recommends to multiply variable load Q by partial factor γ_Q =1.3, but not reducing surcharge pressure at the level of the foundation base). Will not this fact induce lower estimations of the characteristic values of c_u by geotechnical engineers?

(8) Is for this case of bearing resistance better to apply partial factor for material - angle of shearing resistance - directly on ψ or on tan ψ ? Should this factor be constant or progressive ?

(9) Are we really able to determine ψ with higher accuracy than c ?

(10) Can we use some additional partial factors to cover the inaccuracy (differences) between individual methods for overall stability (e.g. 1.1) and also to cover differences between cases, where failure can be associated with different risk (so called partial factor expressing "significance of the structure" - e.g. varying between 1.1 and 1.2)?

(11) What is your experience in the field of determination of total settlement which is very close to the measured one?

Simon Wheeler

(12) In the light of improved understanding of the mechanics of unsaturated soils, are there reliable and straightforward calculation procedures available to practitioners for predicting the movements of shallow foundations constructed on unsaturated soils (including movements caused by wetting and drying)?

(13) What forms of laboratory or in-situ testing are best-suited to providing the appropriate soil data for use in foundation design calculations involving unsaturated soils?

resent a very interesting and preliminary series of centrifuge model

LIST OF PAPERS REVIEWED IN TECHNICAL SESSION 2C

Ali Jawaid, S.M., Madhav, M.R. Continuum approach for analysis of short composite caisson foundation.

Ameratunga, J., Shaw, P., Beohm, W.J., Boyle, P.J. Seawall construction in Moreton Bay, Brisbane.

Blackburn, J.T., Sylvester, K., Finno, R.J. Observed bracing responses at the Ford Design Center excavation.

Boyko, I., Saharov, O., Nemchynov, Yu. The peculiarities of stress-strain state at interaction of high rise buildings and structures with the base.

Bustamante, M., Bourgeois, E., Gianeselli, L., De Justo, J.-L. The foundations of the 2nd railway bridge of Argenteuil.

Chua, H.Y., Bolton, M. Modeling of horizontal earth pressures on retaining walls.

Compagnucci, J.P. Underpinning of foundations in collapsing soils.

Eslami, A., Gholami, M. Bearing capacity analysis of shallow foundations from CPT data.

Gebreselassie, B., Kempfert, H.-G. Mobilization of the earth resistance of a normally consolidated cohesive soils.

Gong, J.F., Huang, X.L., Teng, Y.J. Rigidity characteristic and deformation calculation of large-area thick raft foundation.

Goodey, R.J., McNamara, A.M., Taylor, R.N. The effectiveness of buried mass concrete thrust blocks as a means of lateral support for excavations.

Graterol M., J. The relevance of the yield shear strength of plastic clays in the bearing capacity of foundations.

Hsi, J.P., Yu, J.B.Y. Jet grout application for excavation in soft marine clay.

Ilyichev, V.A., Konovalov, P.A., Nikiforova, N.S. Deformations of the buildings located near foundation trenches and underground excavations and the measures for their reduction.

Isobe, K., Kimura, M. Mechanical behavior of caisson foundation reinforced by steel pipe sheets piles.

Jafarzadeh, F. Vibration isolation of foundations subjected to impact loads by open trenches using physical models.

Katzenbach, R., Bachmann, G., Gutberlet, C. Pile-Soil-Wall-Interaction during the construction process of deep excavation pits.

Korff, M., Herbschleb, J. Validation of design methods with in situ monitoring of deep excavations.

Koseki, J. A simplified procedure to evaluate earthquake- induced displacement of gravity type retaining walls.

Lin, D.-G., Woo, S.-M. Geotechnical analyses of Taipei International Financial Center (Taipei 101) Construction Project.

Marten, S., Delattre, L., Pioline, M., Vinceslas, G., Joignant, Ph., Lavisse, J. Observed behaviour of a quay wall at the new 'Port 2000' at Le Havre, France.

Mecsi, J., Gokalp, A., Duzceer, R. Densification of hydraulic fills by vibroflotation technique.

Moormann, Ch., Humpf, K. Foundation design for a new cable-stayed bridge crossing the Panama Canal.

Ng, C.W.W., Lee, C.J, Xu, G.M., Zhou, X.W. Novel centrifuge simulations of restoration of building tilt.

O'Brien, A.S., Hardy, S., Farooq, I., Ellis, E.A. Foundation engineering for the UK's new national stadium at Wembley.

Portugal, J.C., Portugal, A., Santo, A. Excavation induced building damage.
Quick, H., Keiper, K., Meissner, S., Arslan, U. Complex foundation design in inhomogeneous ground conditions for a high-rise building in Frankfurt, Germany..
Placzek, D. Load bearing capacity of large-size, circular excavation walls without horizontal supporting systems.
Raithel, M., Gebreselassie, B., Müller, S., Pahl, F. Design and numerical investigations of a deep excavation for a tunnel entrance pit.
Reul, O., Ripper, P. Foundation of a tall building in cavernous limestone.
Song, E., Lou, P., Lu, X. Back analyses and safety prediction for an extremely deep foundation pit during its excavation.
Takahashi, K., Okochi, Y. A study on the method for design and construction management considering strain level of ground during excavation.
Taranov, V.G., Shvets, N.S., Shvets, V.B. Some problems of the founding of the powerful turbo-generator sets.
Wichman, B.G.H.M., Allersma, H.G.B. Centrifuge modeling of soil upheave by expanding tubes.

REFERENCES

Charles W.W. Ng 2005. General Report on Technical Session 2c: Excavation, Retaining structures and Foundations, 16th ICSMGE Osaka.