Megacities and New capital: General Report of TC305 Session and Workshop

Megacities et New Capital: Rapport général sur la session et l'atelier TC305

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ABSTRACT: Eight papers from the submittals were selected to TC305 session of 19ICSMGE. Four of them are from Asia: China (1), Chinese Taipei (1), India (2); two are from Europe: France (1), Spain (1); two are from South America: Mexico (2). The subjects of these papers include: geo-environmental technology, underground structure, deep foundation system, seismic hazard analysis, TBM technology and assessment, ground subsidence, subsoil characterizations, and heave problem with countermeasures. In addition, six honorable papers (Chinese Taipei (1), Germany (1), Japan (1), Korea (1), Russia (1), and USA (1)) were invited for TC305 workshop. A summary of these papers are presented in this report.

RÉSUMÉ: Huit documents des soumissions ont été sélectionnés à la session TC305 du 19ICSMGE. Quatre d'entre eux proviennent d'Asie: Chine (1), Taipei chinois (1), Inde (2); Deux d'Europe: France (1), Espagne (1); Deux d'Amérique du Sud: le Mexique (2). Les sujets de ces documents comprennent: la technologie géo-environnementale, la structure souterraine, le système de fondation profonde, l'analyse des dangers sismiques, la technologie et l'évaluation TBM, l'affaissement au sol, les caractérisations du sous-sol et le problème de contraction avec les contre-mesures. En outre, six articles (Taipei chinois (1), Allemagne (1), Japon (1), Corée (1), Russie (1) et Etats-Unis (1)) ont été spécialement invités pour l'atelier TC305. Un résumé de ces articles est présenté dans ce rapport.

KEYWORDS: megacities, new capitals, geo-technologies.

1 INTRODUCTION

The 19th International Conference on Soil Mechanics and Geotechnical Enginering (19th ICSMGE) is to be held in Seoul , Korea on September 18-22, 2017. A tecnical session of TC305 on Geotechnical Infrastructure for Megacities and New Capitals has been scheduled with the kind assistance from the organizer. Eight papers have been selected from the contributed ones from member societies at different regions for presentations at TC305 Session at 19ICSMGE. In addition, there is a TC305 workshop scheduled, six honoable papers were invited for selecetive technologies demoed for design and construction practice. This report simply summarizes the papers presented at both the session and the workshop.

2 PAPERS OF THE SESSION

2.1 Effect of lead contamination on compression index and hydraulic conductivity of clayey soil-bentonite backfills for slurry-trench cutoff walls

The study made by **Du *et al.*** presents the results of several oedometer tests to investigate the compression index (C_c) and k of clayey soil-bentonite backfills exposed to lead (Pb), which is frequently encountered in contaminated groundwater and subsurface soils. The results demonstrate that Pb contamination has resulted in significant decrease in C_c while increase in k of clayey soil/Ca-bentonite backfills for slurry-trench cutoff walls. The extent of changes in these two properties is crucially affected by Pb concentration. A systematic analysis of the test results from this study and previous studies is made to develop generalized methodology for predicting the C_c and k of metal-contaminated soils. The results were reported to be very useful in exploring long-term contaminant containment performance of clayey soil/Ca-bentonite slurry-trench walls.

2.2 Displacement of ground and diaphragm wall induced by deep excavations in loose to medium dense sand

A unique report has been made by **Hsiung and Yang** on investigations of ground and structural performances induced by deep excavations in loose to medium dense sand. Observations of the excavation are briefly described in this paper and it is found that the ratio of maximum lateral wall movement to the excavation depth is 0.32%. The observed surface settlement tends to be smaller due to the limited allowable measurement distance to the excavation site. In addition, deeper impermeable clay might also be the reason leading to smaller surface settlement. A series of numerical analyses is conducted to predict excavation-induced deformations using PLAXIS 2D. The accuracy and effectiveness of three constitutive models, namely Mohr-Coulomb (MC), Hardening Soil (HS) and Hardening Soil with Small Strain (HSS) models, are evaluated. The results have demonstrated that the HSS model yields the best predictions for the wall deflections and ground surface settlements, as for the MC model shows the largest discrepancy. The comparison result is apprehended to be linked with definition of soil stiffness in the model.

2.3 *Deep foundation systems of ultra high-rise buildings: the Entisar tower in Dubai*

Pereira *et al.* presents the foundation system of Entisar Tower in Dubai. At over 500 m in height, it will be one of the tallest buildings in the world. With a footprint of 60 m by 60 m, it is a very slender structure, inducing very high compression stresses on its base, and therefore requiring a specific deep foundation system, consisting of rectangular barrettes with high-performance concrete, up to 80 m in depth, embedded in soft

rock. The paper details the development of both the design process and the challenges of foundation testing and construction. The general geotechnical context, the site investigation and the return of experience from previous Dubai projects are described. The 2D and 3D numerical modeling, used during the design and the review of the design, are specifically addressed. A particular emphasis is made on the various stages of soil structure interaction procedures and the iterative design process. In order to validate the design assumptions, several barrette tests with multi Osterberg cells have been performed. Finally, the monitoring program and the progress of the ongoing construction works are presented.

Figure 1. Entisar Tower illustrations (from Pereira *et al.*)

2.4 *Seismic Liquefaction Hazard-Vulnerability Analysis and Mapping of Existing Important Buildings of Mumbai City, India*

Paskar-Phule and Choudhury discussed the behaviors of the predominantly saturated sandy soil that is 2m to 3m thick in Mumbai city of India, which is likely to be subjected to seismic liquefaction during moderate to high earthquake magnitudes (M_w) of greater than 6.5. In their paper, seismic liquefaction hazard-vulnerability-risk analysis and mapping of existing important buildings of Mumbai city are carried out in ArcGIS platform. The seismic liquefaction of the sandy soils of Mumbai city is estimated in terms of probability (PL) of failure and the vulnerability is assessed as Overall building Vulnerability Index (VIo). One square kilometer grid based estimated PL and VIo are computed for the entire Mumbai city, and are combined for preparing liquefaction risk maps for Mumbai city for different earthquake magnitudes (M_w). The liquefaction risk maps show *that some of the areas of Mumbai city lie in moderate to severe* liquefaction zones having risk value ranging between 0.5 and 1.0. These risk maps can be helpful to predict the extent of damage caused to the existing important buildings due to liquefaction, to take action against prevention of liquefaction hazard, and for planning rescue and recovery operations during earthquake hazard.

2.5 *TBM- Ground Interaction Modelling*

With the knowledge that TBM technologies can cause damages to adjacent buildings without further attentions, **Boominathan and Banerjee** present a study focuses on a closed-face pressurized tunneling concept where all the relevant components of a mechanized tunneling process like application of face pressure, cutter head torque, tail grout pressure, back- up trailer weight and shield- skin friction, soil removal, shield removal, lining installation and grout hardening are numerically modelled, for a shallow tunnel of 8.0 m diameter. Tunneling is carried out in stiff clay at a depth of 19.0 m from the ground surface. Ground response in terms of deformation and pore pressure is monitored at critical locations for each excavation. As the tunneling progressed, changes in these parameters could be very well established in the numerical analysis.

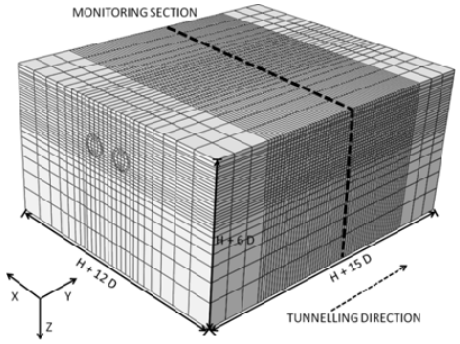

Figure 2. Three dimensional finite element mesh for the underground tunnels excavated using mechanized shield (from Boominathan and Banerjee)

2.6 *Recent information on Mexico City subsidence*

Updated information about regional subsidence in Mexico City is presented in this paper by **Auvinet *et al.***. Topographical data obtained by Gayol in 1891, are compared with the results of recent surveys of the reference points of Sistema de Aguas de la Ciudad de México (SACMEX, 2008) and from the elevations of a cloud of points on the ground surface determined using Light Detection and Ranging (LiDAR) technology. In addition, this paper provides an overview of recent data obtained from systematic studies focused on understanding soil fracturing associated with regional land subsidence and mapping of areas susceptible to cracking in Mexico City Valley.

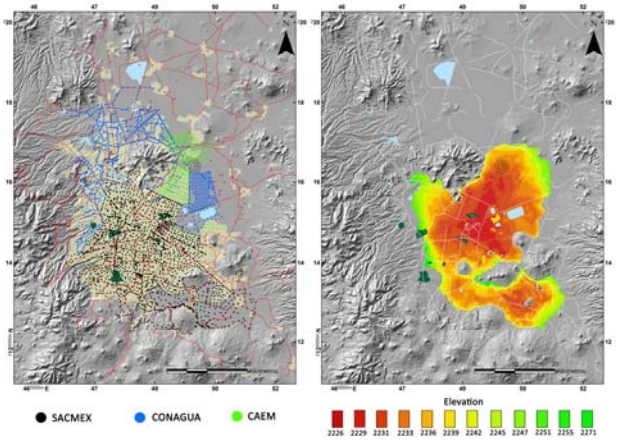

Figure 3. Network of existing benchmarks and results of a LiDAR survey (from Auvinet *et al.)*

2.7 *Subsoil characterization for the railway network of the collective system of public transportation in Mexico City*

The characterization of the subsoil along the railway network of the collective system of public transportation of Mexico City is presented by **Juárez-Camarena *et al.***. The subsoil characterization is based on models of spatial distribution of water content, which are constructed processing the results of a large number of geotechnical explorations and field tests using geostatistical methods. As a result, a set of longitudinal cross-sections of water content along of each railway routes and their corresponding stratigraphic cross-sections are presented.

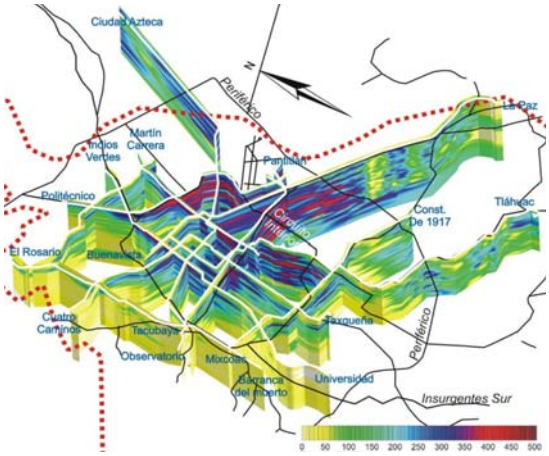

Figure 4. Water content distribution along routes of the railway system (from Juárez-Camarena *et al.*)

2.8 *Heave of a building on Keuper anhydritic formation*

The development of fissures in a building placed at the site of an ancient quarry excavated in a Keuper formation motivated a detailed in-situ investigation of the foundation material. **Ramon and Alonso** discussed the findings in this paper. Severe fissures and cracks were present at the partition walls of the basement and ground floor of the building. Swelling and local failures were also observed at the basement floor slab. The observed cracks suggested that the damage was related to differential movements of the foundation of the building. Levelling of basement floor, pillars and walls allowed the identification of a slow systematic heave of some pillars. The records of vertical displacement along depth of two continuous extensometers installed at the basement indicated that the heave displacement was associated with the expansion of the four upper meters of the foundation material. Mineralogical investigation by means of X-ray diffraction analysis identified anhydrite and gypsum in samples recovered from boreholes. The most probable expansive mechanism is the precipitation of gypsum in depth, which will most likely take place in fractures of the foundation material. Solutions advanced to counteract the heave are also discussed in the paper.

3 PAPERS OF THE WORKSHOP

3.1 *Geotechnical Infrastructure in Taipei Metropolis*

Moh and Hwang introduced the advanced technologies which were applied in a metropolis. Rapid development of infrastructure in the past 50 years or so has drastically improved the quality of life in Taipei metropolis. Construction with significant geotechnical contents started with the sewage system and 2 open type shield machines were used for the first time in 1976, followed by the Railway Underground Project, Metro System, High Speed Rail, and lastly the Taoyuan International Airport Access MRT. The metro system is of particular interest to geotechnical engineers because the excavations were very deep and the presence of a highly permeable water-rich gravel layer frequently led to failures. The soft nature of the young deposits also presented serious challenges. Described in this paper are a few innovative construction techniques to deal with difficult situations.

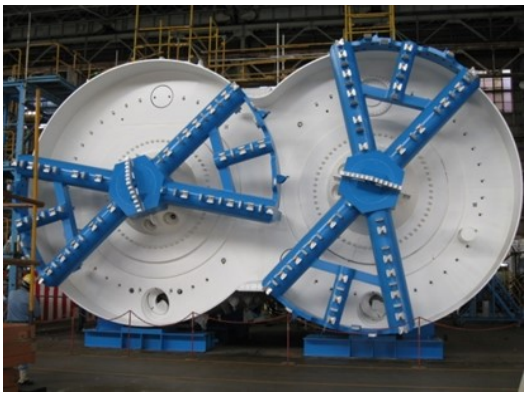

Figure. 5. Double-O-Tube shield machine and concrete linings (from Moh and Hwang)

3.2 *St. Isaac's Cathedral: Behavior of a Historical Monument in St. Petersburg (Russia)*

In the paper presented by **Shidlovskaya and Briaud**, the foundation preservation technology for historical monument was introduced. St Isaac's Cathedral in St. Petersburg was completed in 1858 after 40 years of construction; it is today the fourth largest domed Cathedral in Europe. The soil is relatively soft saturated sediment and carries this 3138 MN structure which is 100 meters high with an imprint of 92 by 102 m. It is founded on a 7.5 m thick mat of granite and limestone blocks resting on relatively short timber piles of different lengths. The Cathedral has progressively experienced significant deformation including differential settlement causing cracks in the pillars and tilting of the porticoes. The paper summarizes the geotechnical engineering aspects of the soil on which the Cathedral is built as well as classical issues such as foundation ultimate capacity and settlement analysis through simple calculations. The paper concludes by presenting the measurements made over time on the deformation of the Cathedral.

3.3 *Case History of Pre-Supported Tunnelling Method in Weak Weathered Rock*

Shin *et al.* presents a paper on case histories of pre-supported tunneling method in weak weather rock. Construction of underground tunnel in the densely populated area is great challenge for geotechnical engineers. Sometimes a wide section tunnel passes through the area of partially weathered rock with a thin cover soils. The stability of superstructures are all the time problem during the construction of tunnel like this geological situation. In this paper, Korean pre-supported tunnelling method (KPST) in corporate with pre-nailing as well as pilot tunnelling technique is presented to improve the tunnel stability and reduce the probable tunnel deformation by grand arching effect of the reinforcement. Finally one case history of 321m-long tunnel construction in the completely weathered and fractured dark shale by using KPST method is presented with detail construction sequences.

3.4 *Geotechnical challenges shaping the infrastructure for Megacities - (Practical aspects and case studies)*

The paper contributed by **Sondermann** introduced geotechnical challenges for megacities. Current market conditions creating new future challenges for the construction industry in combination with the decreasing demand for construction at least in well-developed regions, it becomes more and more important to gain competitive advantages through innovative solutions in order to deal with the continuing pressure on costs,

schedule and quality also. For geotechnical engineers the main future challenges are to be familiar with theoretical as well as practical geotechnical applications to identify the optimal combination of technologies including the best design approach to be competitive for a specific project.

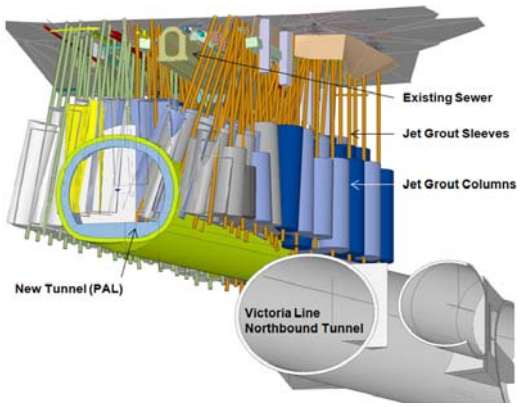

Figure 6.. Arrangement of Soilcrete columns, modelled with GeoBIM (from Sondermann)

3.5 *Application of X-ray CT in geotechnical engineering*

In the paper of **Otani**, a new technology with X-ray is introduced. An X-ray CT was developed as a diagnosis method on human body and recently, this apparatus has been used in science and engineering. The author started to study on the application of X-ray CT in geotechnical engineering in 1996. In this paper, a brief introduction of X-ray CT with its fundamental issues is summarized at first. Then, since the session theme is "Geotechnical Infrastructure for Megacities and New Capitals" under TC305, one of the application studies which is the problem on tunneling is discussed. Here, the mechanism of face failures of tunneling which are both active and passive types are presented in details. Finally, the salient future on the application of X-ray CT in geotechnical engineering is stated

3.6 *Eexperience in Construction and Design Justification of the Technology of Underground Structures in Moscow*

The report made by **Ilyichev** examines the impact of the technology of erecting an underground structure on its final stress-strain state. As examples, are given real construction objects. Also are described advantages of the developed approach – technological mechanics of soils.

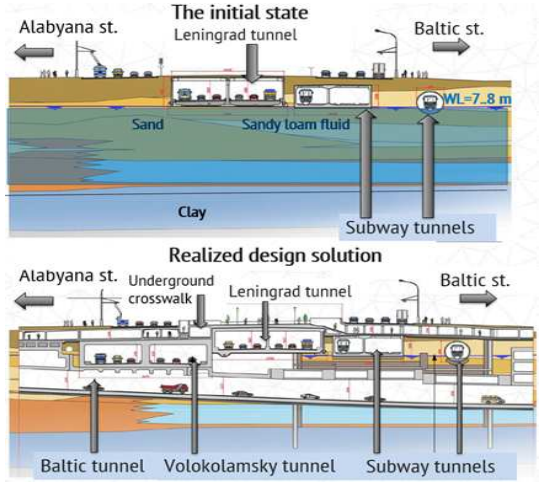

Figure 7. Alabian-Baltic tunnel developments (from Ilyichev)

4 SUMMARY

From the papers presented at both the TC305 Session and Workshop, one can notice that there are many different technologies that have been adopted in solving the complexities involved in the practice of geotechnical work for urban zones and metropolitan areas. Existing design, analysis and construction methods need to be continuously improved. In addition, advanced dada information and geodetic technologies were developed and have been adopted comprehensively to deal with more complicated geotechnical challenges. The applications of these technologies are selectively presented at the 19th ICSMGE.

5 REFERENCES

Auvinet, G., Méndez, E., Juárez, M. 2017. Recent information on in Mexico City subsidence, *Procds.*, 19ICSMGE, Sep. 18-22, Seoul

Boominathan, V.K. and Banerjee, S. 2017. TBM- ground interactio n and the effect on adjacent structure integrity, *Procds.*, 19ICS MGE, Sep. 18-22, Seoul

Du, Y.J. Fan, R.D., Liu, S.Y., Liu, Z.B, Wang, F. and Yu, C. .2017. Effect of Lead Contamination on Compression Index and Hyd raulic Conductivity of Clayey Soil-Bentonite Backfills for Slur ry-Trench Cutoff Walls, *Procds.*,19ICSMGE, Sep. 18-22, Seoul

Hsiung, B. and Yang, K.H. 2017. The analysis of ground and stru cture displacements induced by deep excavations in loose to medium dense sand, *Procds.*,19ICSMGE, Sep. 18-22, Seoul

Ilyichev, V. 2017. Experience in Construction and Design Justification of the Technology of Underground Structures in Moscow, *Procds.*, 19ICSMGE, Sep. 18-22, Seoul

Juárez-Camarena, M., Auvinet, G. and Méndez-Sánchez, E. 2017. Subsoil characterization for the railway network of the collecti ve system of public transportation in Mexico City, *Procds.*, 19 ICSMGE, Sep. 18-22, Seoul

Moh, Z.C. and Hwang, R.N. 2017. Geotechnical Infrastructure in Taipei Metropolis, *Procds.*, 19ICSMGE, Sep. 18-22, Seoul

Otani, J. 2017. Application of X-ray CT in geotechnical engineering, *Procds.*, 19ICSMGE, Sep. 18-22, Seoul

Pereira, G., Lam, P., Jeanmaire, T., Poulos, H., Bergère, A. 2017. Deep foundation systems of ultra high-rise buildings: the ENT ISAR tower in DUBAI, *Procds.*,19ICSMGE, Sep. 18-22, Seoul

Ramon, A. and Alonso, E. 2017.Heave of a building founded on Keuper anhydritic formation, *Procds.*, 19ICSMGE, Sep. 18-22, Seoul

Raskar-Phule R. and Choudhury D. 2017. Seismic Liquefaction Ha zard-Vulnerability Analysis and Mapping of Existing Important Buildings of Mumbai City, India, *Procds.*, 19ICSMGE, Sep. 1 8-22, Seoul

Shidlovskaya, A. and Briaud, J.L.2017. St. Isaac's Cathedral: Behavior of a Historical Monument in St. Petersburg (Russia), *Procds.*, 19ICSMGE, Sep. 18-22, Seoul

Shin, E.C., Kim, J., Lee, A., Kwon, O.H., Seo, D.H. 2017. Case History of Pre-Supported Tunnelling Method in Weak Weathered Rock, *Procds.*, 19ICSMGE, Sep. 18-22, Seoul

Sondermann, W. 2017. Geotechnical challenges shaping the infrastr ucture for Megacities - (Practical aspects and case studies), *Pr ocds.*, 19ICSMGE, Sep. 18-22, Seoul