



Seventh  
International Conference on  
**Case Histories in  
Geotechnical Engineering**

*and Symposium in Honor of Clyde Baker*

## GENERAL REPORT – SESSION 1

### 1a. Application of Case Histories to Practice

### 1b. Application of Case Histories to Education

### 1c. Observational Method, Successes and Failures

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## INTRODUCTION

Civil Engineers are responsible for health, safety, and welfare of the public and are always challenged with improving the quality of life. Although the profession of civil engineering is one of the oldest engineering professions, geotechnical engineering branch of civil engineering is relatively young and is born out of necessity to understand failures in earth materials. Many of theoretical concepts and geotechnical models which are in use today were developed to match the features of geotechnical failures. These concepts and models are being updated regularly based on the new information learned from case histories. In short, case histories play a critical role in the design, construction, and successful performance of every civil engineering project. Therefore, the theme on application of case histories in practice and education has become an integral part of the Case Histories in Geotechnical Engineering Conference. In order to properly organize vast amount knowledge on this topic, Session 1 has been divided into three sub-sessions as shown in Table 1.

A total of 45 papers, contributed by engineering educators and practitioners from 16 countries, have been accepted for this session. Table 1 shows the number of papers received for each sub-session and Table 2 presents the list of all papers received for this session, organized in the order of paper numbers. The work contributed for the session provides a true global view on the use of geotechnical engineering case histories in education and practice, and application of observational methods in the practice of geotechnical engineering.

Summary of each paper submitted on the topic related to this session is presented in this report which provides a general overview of the paper. However, in order to take full benefit of the information presented by the authors, readers are encouraged to review the entire paper.

Table 1: Description of Session 1

Session	Session Title	Description of Each Session	# of Papers Received
Session 1a	Application of Case Histories to Practice	Use of Case Histories to Enhance Practical Geotechnical Engineering; Practice in Different Offices to Achieve this Objective with Examples; Importance of Life Long Learning; Use of Case Histories in Life Long Learning	19
Session 1b	Application of Case Histories in Education	How Case Histories have been incorporated in coursework; How to Conduct Search for Case Histories, and What are the Major Sources; Examples of Specific Use/s: Importance of Teaching Case Histories; From Case Histories to Conceptual Models; Importance of Practical Experience of Professors; Use of Case Histories in Teaching Process; Is it possible to Involve Students in Case Histories (i.e. in Engineering Practice)?	13
Session 1c	Observational Method, Successes and Failures	Case Histories of the Successful Application of the Observational Method and Observational Control; Critically Reviewed Old Case Histories (post mortem) and Successful Case Histories; Architecture of Reporting Case Histories, and The Question of Ethics in Reporting of Case Histories; History of Geotechnical Engineering; Ancient Geotechnical Engineering	13

Table 2: List of Papers Organized based on the Sub-Session Number and Paper Number

Paper	Country	Authors	Title
<b>Session 1a: Application of Case Histories to Practice</b>			
1.02a	Poland	Marek Tarnawski	Geotechnical Failures Caused by Human Errors
1.04a	China	Wang Wei-dong, Wu Jiang-bin, Weng Qi-ping	Foundation Design and Settlement Measurements of CCTV New Main Building
1.07a	USA	Kam Ng, Jessica Garder, Sri Sritharan, Jeramy Ashlock	An Investigation of Load and Resistance Factor Design of Drilled Shafts using Historical Field Test Data
1.08a	India	Mahesh D. Desai, Jignesh B. Patel, Nehal H. Desai	Application of Case Studies to Practice in Foundation Engineering in India
1.10a	Colombia	Camilo Marulanda, Alberto Marulanda, Camilo Phillips	Experiences in Large Slope Stability Problems under Complex Geology
1.11a	USA	Michael R. Lewis, Ignacio Arango, Kenneth Stokoe, II	Liquefaction Resistance of Gravelly Soils
1.12a	USA	Derrick Dasenbrock, Aaron S. Budge, Bryan Field, Daniel Mattison	Performance Monitoring of a Bridge Abutment Spread Footing Foundation from Construction through Service
1.13a	Italy, Australia, UK, Italy	Francesco Petrella, Roberto Persio, Silvia Ferrero, Tim Hocombe	Behavior of a Large Anchored Basement in Dense Sands and Gravels
1.14a	USA	Michelle Shriro, Jonathan D. Bray	Calibration of Numerical Model for Liquefaction-Induced Effects on Levees and Embankments
1.15a	USA	Said Iravani	Composite Shallow & Deep Foundation in Karst Geology for the Countryside Christian Center New Sanctuary, Clearwater, Florida
1.16a	USA	James Saldaña	Insurance Industry Perspective on the Importance on Geotechnical Earthquake Engineering for Commercial Structures
1.18a	India	Ram Bachan Shivali, Rakesh Mahajan	Geotechnical Investigation at Barrage for Foundation Design at NYAMJANG CHHU Hydro Power Project, Tawang, Arunachal Pradesh, India - A Case Study
1.21a	USA	Swaminathan Srinivasan, Aaron J. Muck	Numerical Modeling and use of Settlement Reducing Auger Cast-in-Place Piles Below a Mat Foundation
1.22a	Canada,	Myint Win Bo, Arul	Planning and Implementation of Mega Geotechnical Engineering Projects in

	Australia	Arulrajah	Singapore
1.23a	Iran	Reza Behrou, Mohammad Reza Ghayamghamian	Recorded Bedrock Motions and Site Effects Evaluation in Tehran City
1.24a	Iran	Reza Behrou, Mohammad Reza Ghayamghamian	Site Effects Estimation in Tehran City by Using Empirical Methods
1.26a	Italy	Antonio Cavallaro, Antonio Ferraro, Salvatore Grasso, Michele Maugeri	Site Response Analysis in the STM-M6 Industrial Area of the City of Catania (Italy)
1.27a	Egypt	Marawan Shahien, Ali Hefdhallah	Effect of Neighboring Footings on Single Footing Settlement
1.28a	USA	Abdul Aziz Khandker, Jeffrey T. Anagnostou, P.D. Deo	Geotechnical Challenges in Highway Engineering in Twenty First Century: Lessons from Past Experiences and New Technologies
<b>Session 1b: Application of Case Histories in Education</b>			
1.01b	India	R. Shivashankar	Role of Case Histories in Geotechnical Engineering Teaching and Practice
1.02b	USA	Waddah Akili	On Becoming a 21st Century Engineering Educator: Building Competencies and Acquiring Needed Skills
1.03b	USA	Waddah Akili	Enhancement of Engineering Education in the Arab States through Cooperative Learning Protocols
1.04b	Italy	Diego Lo Presti	An Example of Teaching Slope Stability from True Case Histories
1.05b	USA	James Mahar	Case Histories in Geotechnical Engineering Education
1.06b	Hungary	Richard Ray, Peter Scharle, Robert Szepesházi	Case Studies - Pavement of the Educator's Road
1.07b	USA	Rajaram Janardhanam, Miguel A. Pando	Geosynthetic Reinforced Segmental Retaining Wall Failure: Forensic Investigation and Remediation
1.09b	Canada	Benoît Courcelles, Lina Forest, Anastassis Kozanitis	Students as Forensic Engineers: An Innovative Approach to Teaching Soil Mechanics
1.10b	USA	Andrew T. Rose	Using Local Case Histories in Undergraduate Teaching
1.11b	USA	Andrew T. Rose	Using the 1911 Austin Dam Failure Case History in Undergraduate Teaching
1.12b	Greece	George Belokas, George Dounias, Marina Pantazidou, Christos Tsatsanifos	The Initiative of the Hellenic Society for Soil Mechanics and Geotechnical Engineering to Support the Development of Case Studies Suitable for Instruction & a Slope Stability Example
1.14b	Malaysia	Chee-Ming Chan	"Extreme Foundations" for Peat Deposit: Conceptual Models, Creative Thinking and Learning Process
1.15b	Ireland, Greece	Trevor L. L. Orr, Marina Pantazidou	Case Studies Used in Instruction to Achieve Specific Learning Outcomes: The Case of the Embankments Constructed for the Approach to Limerick Tunnel, Ireland
<b>Section 1c: Observational Method, Successes and Failures</b>			
1.01c	Iran	Reza Amini Ahidashti, Abdolhosain Hadad	A Non-Linearity Method to Estimate Elastic Settlement of Shallow Foundations Using Small-Strain Stiffness
1.02c	India	Gokul K. Bayan	Performance of Digboi Refinery Modernization Project from Geotechnical Aspects – Investigation and Observations
1.03c	India	Indra Prakash	Application of Observational Method in the Successful Construction of Underground Structures, Sardar Sarovar (Narmada) Project, Gujarat, India
1.04c	Canada	Yadav Pathak, Brian Hall, Marc Sabourin, Jake Brucker	Braced Sheet Pile Shoring Wall in Sensitive Clay
1.05c	USA	Adolfo C. Caicedo-Aspiazú, Nelson Caicedo	Case Study: Application of the Observational Method using High Strain Dynamic Tests
1.08c	Germany	Patrick Becker	Importance of Observational Method in View of Numerical Analyses for Retaining Structures in Soft Soils

1.10c	USA	Stephen M. McLandrich, Youssef M.A. Hashash, Nick J. O’Riordan	Networked Geotechnical near Real-Time Monitoring for Large Urban Excavation using Multiple Wireless Sensors
1.12c	Iran	Mehdi Derakhshandi, Mojtaba Honarmand, Amir Hossein Sadeghpour	A Comparison of Three and Two Dimensional Analyses of Rockfill Dams in Narrow Valleys (A Case Study - Vanyar Dam)
1.14c	USA	Timothy H. Bedenis, Christopher G. Nadia	Use of the Observational Method to Verify Design of Earth Retention Structures
1.15c	USA	Charles B. Grant, Tom Hurley	Case History - Performance Monitoring Success
1.17c	USA, China	Dr. Kul Bhushan, Ken Choudhary	Design of Shallow Foundations for a Large Polysilicon Plant in China
1.19c	Italy	Francesca Bozzano, Paolo Mazzanti, Alberto Prestininizi	Supporting Tunnelling Excavation of an Unstable Slope by Long Term Displacement Monitoring
1.20c	India	D.S. Subrahmanyam, S Sengupta, R K Sinha, G Shyam	Determination of In-Situ Stress at Desilting Chamber of Punatsangchhu Hydroelectric Project (Bhutan), to Reconfirm its Orientation Influenced by Topography - A Case Study

## SUMMARY OF PAPERS

### Session 1a: Application of Case Histories to Practice

Paper 1.02a, **GEOTECHNICAL FAILURES CAUSED BY HUMAN ERRORS**, by Marek Tarnawski: Marek Tarnawski from The West Pomeranian Technical University, Poland, has prepared a monograph entitled “Geotechnical reasons of building failures”, which includes 225 case studies. This, in turn, enables categorization of such failures and devising ways to prevent them in the future. Even though most described cases are local to Poland, many findings would surely prove applicable in many other countries, as well. The analysis of particular cases indicates that even those natural reasons should have been anticipated by participants of construction process and appropriate remedial measures should have been taken up. Authors conclude that in all failures caused by geotechnical reasons, humans and not the nature is to be blamed.

Paper 1.04a, **FOUNDATION DESIGN AND SETTLEMENT MEASUREMENTS OF CCTV NEW MAIN BUILDING** by Wang Wei-dong, Wu Jiang-bin and Weng Qi-ping: This paper presented a case study on design of China Central Television (CCTV) New Main Building which is situated in Chaoyang District of Beijing. The building consists of two main towers and podiums. As the two towers with 54 and 44 stories respectively are leaning 6 degree from vertical and connected with overhanging L shape podiums, load transfer mechanism onto the foundation generated uneven load distributions. In order to optimize pile length a suitable formations for end bearing were carefully selected. The bored piles with diameter of 1200mm and length of 33.4 and 51.7 m with single pile bearing capacity of 11000kN were designed for the towers. Using the combination of pile-end and shaft grouting, as well as in-situ load tests of piles with different pile length, the pile length, the costs and construction difficulties were managed to minimize. Test pile results confirmed that both 33.4 and 51.7 m piles embedded on the competent formation at -14 m

elevation and -32.3 m elevation achieved the capacity of as high as 30,000 kN. Based on the concept of interactions among the superstructure, the foundation raft, the piles and soils, calculations and analysis were carried out on the design of the piles and raft applying finite element modeling to ensure the settlements and internal forces to be kept at allowable levels. Field monitoring of the settlements, internal forces of raft, reaction forces at pile tops, water and earth pressures etc. were carried out during the construction process. The data of field settlement measurements were then studied and verified the design predictions.

Paper 1.07a, **AN INVESTIGATION OF LOAD AND RESISTANCE FACTOR DESIGN OF DRILLED SHAFTS USING HISTORICAL FIELD TEST DATA** by Kam Ng, Jessica Garder, Sri Sritharan and Jeremy Ashlock: This paper discussed development of the Load and Resistance Factor Design (LRFD) approach which required by the Federal Highway Administration (FHWA) for all types of foundations including drilled shaft. As the first step in developing efficient regional LRFD procedures for drilled shafts, the Drilled SHAFT Foundation Testing (DSHAFT) database was formulated. DSHAFT was aimed at assimilating high quality, historical drilled shaft test data from Iowa and the surrounding states, and it presently contains data from 41 drilled shaft load tests, 38 of which are O-cell load tests, along with subsurface information and structural details. Authors reported that the application of the historical data was restricted by several challenges associated with subsurface investigations, determination of geomaterial properties and test methods employed in the current practice for drilled shaft capacity estimations. Another challenge identified in this study is attributed to typical O-cell test results from which the equivalent top load-displacement curves are generated. Many of these curves do not pass the desired displacement-based design criteria that define the ultimate measured resistance. To overcome this challenge, authors developed a procedure to

generate equivalent top load displacement curves from O-cell tests to facilitate the development of regionally calibrated LRFD resistance factors in accordance with any displacement-based design criterion. This procedure is demonstrated to three different load test cases, referred as A, B and C. Using the proposed procedure and LRFD framework, authors demonstrated that robust, more efficient regional LRFD resistance factors can be established for drilled shafts with a target displacement limit. In summary, the proposed procedure improved the development of the LRFD approach and facilitated more efficient and more dependable regional LRFD calibration for drilled shafts that accounted for the local soil conditions.

Paper 1.08a, APPLICATION OF CASE STUDIES TO PRACTICE IN FOUNDATION ENGINEERING IN INDIA by Mahesh D. Desai, Jignesh B. Patel, Nehal H. Desai: The Authors have discussed about the optimization of cost and saving construction time for completion of various projects related to foundation engineering in India. Authors have prepared a report on ground characterization by in-situ testing and have advocated the importance of bore holes to be supplemented by uncased DCPT. It has been recommended that probable liquefaction of existing or under construction projects must be checked by proper reinvestigations and interpretation of results. Authors have cautioned designers against the practice of blindly following geotechnical investigation report and have urged them to rely more on the experience based judgment, which is based on the inputs from the geological history of site.

Paper 1.10a, EXPERIENCES IN LARGE SLOPE STABILITY PROBLEMS UNDER COMPLEX GEOLOGY by Camilo Marulanda, Alberto Marulanda and Camilo Phillips: The authors have presented three case histories related to the effect of weak zones in the metamorphic rock mass, especially schist, which cause significant slope stability problems. Significance and importance of continuous geological investigations, sensibility analysis of shear strength parameters, well developed geological and geotechnical models to define the real behavior of the unstable zones and sound and efficient stability measures has been emphasized. It has been opined that as a result of the clay composition, porewater pressures increase which triggers landslides. Authors have highlighted the importance of providing the adequate drainage system (viz., galleries or directed boreholes).

Paper 1.11a, LIQUEFACTION RESISTANCE OF GRAVELLY SOILS by Michael R. Lewis, Ignacio Arango, and Kenneth Stokoe, II: This paper describes an approach used to assess the liquefaction potential of the gravel deposits at a remote site in British Columbia, using existing published relationships and case history data on similar soils. The cyclic resistance ratio (CRR) for the upper sand and gravel deposits was characterized based on the material mechanical properties, measured shear wave velocities and in-situ density data obtained from shallow test pits excavated across the site.

To assess the liquefaction potential, two methods (Hardin and Drnevich, and Menq) were used to estimate small-strain shear modulus and eventually shear wave velocity. Straight forward field and laboratory tests were used to correlate shear wave velocity with void ratio; and void ratio was then related to the CRR using published relationships on a similar gravelly soil tested in the laboratory. The liquefaction potential was assessed in the conventional manner comparing the CRR (after appropriate consideration of correction factors used in laboratory cyclic testing) to the seismic demand (CSR). The approach described in the case history generalizes the methodology for application to other gravel deposits at other sites.

Paper 1.12a, PERFORMANCE MONITORING OF A BRIDGE ABUTMENT SPREAD FOOTING FOUNDATION FROM CONSTRUCTION THROUGH SERVICE by Derrick Dasenbrock, Aaron S. Budge, Bryan Field and Daniel Mattison: The authors reported that use of spread footings over compressible soils is becoming more common for Minnesota Department of Transportation bridges as technologies improve to better predict, mitigate, and evaluate settlement. They reported the use of shallow foundations for the abutment of a new bridge constructed over compressible soils after preloading to reduce the foundation settlement from several inches to less than one inch, to meet project requirements. An application of well planned instrumentation and monitoring program was implemented to validate the preloading technique and to better understand the time dependent behavior of shallow foundation. Instrumentation used consisted of two earth pressure cells, a horizontal MEMS SAA deformation monitoring array, and four optical survey reflectors which were installed during the construction of the foundation and abutment wall.

The authors observed the effect of the various loading and unloading conditions using the sensors. The abutment foundation performance over the construction timeline was discussed, including apparent loading, deflection, and rotation. The authors reported findings on an excellent agreement among the observed times associated with the loading events, and observed pressure and deformation responses in the EPC and SAA sensors. They reported that SAA system appeared to provide good quality, stable, data. Due in part to the high sampling rate and considerable number of data points, the SAA data was easier to interpret than the optical target datasets. The SAA data showed good correlation between the loading events and observed deformations. The precision of the instrument also allowed very small deformations to be effectively monitored for this study. They also reported effectiveness of preloading in reducing post construction settlement. The monitoring program they implemented was successful in showing the foundation performance well within project tolerances and the use of spread footings combined with the ground improvement plan met the project need for serviceability without the extra cost associated with deep foundation systems. Authors concluded that as the majority of the loading appeared to be associated with “early” loading

from the footing, stem, parapet, and soil, it seems reasonable that shallow foundations could be employed even at more marginal sites- particularly those where the settlement is immediate in nature. Monitoring the shallow foundations with optical targets was cost effective and provided useful data to assess that the footing(s) were not settling problematically or to an extent that was outside project tolerances. However, in environments where deformations are small or the project is critical in nature, systems with high precision such as millimeter (0.05 in) precision total station systems or Shape Accel Array systems should be considered to ensure high quality data is captured at a sufficient resolution to meet project needs.

Paper 1.13a, BEHAVIOR OF A LARGE ANCHORED BASEMENT IN DENSE SANDS AND GRAVELS by Francesco Petrella, Roberto Persio, Silvia Ferrero, and Tim Hocombe: The authors have described construction of a long diaphragm wall prior to the excavation of half a million cubic meters of dense gravelly material within the city centre of Milan. Application of ground anchors and a post-tensioned capping beam has been highlighted. An extensive monitoring system has been set up to record and monitor lateral movements and anchor loads. It has been opined that the findings from the study would be quite useful for preparing design guidelines for deep excavations in dense coarse materials. Authors have reported that heave behind the wall could not be fully reproduced in a PLAXIS model with a staged excavation and ground anchor pre-stressing, especially in the final stages of the excavation.

Paper 1.14a, CALIBRATION OF NUMERICAL MODEL FOR LIQUEFACTION-INDUCED EFFECTS ON LEVEES AND EMBANKMENTS by Michelle Shriro and Jonathan D. Bray: This paper describes the calibration process of the nonlinear soil constitutive model UBCSAND, as implemented in the finite difference program FLAC, to capture the seismic deformations of the Moss Landing Marine Laboratory (MLML) in Moss Landing, California resulting from liquefaction-induced lateral movements during the Loma Prieta earthquake of 1989. The UBCSAND constitutive model is a nonlinear stress-dependent effective stress model that captures the build-up of excess pore water pressure during cyclic loading and the development of “banana loops” in the shear stress versus shear strain plot once liquefaction occurs. A material parameter selection protocol was developed through one-element modeling of laboratory testing and then implemented to predict deformations at the MLML facility. The version of UBCSAND employed in this study was edited July 26, 2009. Model input parameters include elastic stiffness, plastic shear stiffness, strength, flow rule, relative density, and four fitting parameters.

Paper 1.15a, COMPOSITE SHALLOW & DEEP FOUNDATION IN KARST GEOLOGY FOR THE COUNTRYSIDE CHRISTIAN CENTER NEW SANCTUARY, CLEARWATER, FLORIDA by Said Irvani: This paper described the application of ground investigation

program which balance between non-intrusive field tests such as Electrical Resistivity Imaging (ERI) or Ground Penetrating Radar (GPR) and intrusive field tests such as SPT and CPT to characterize qualitative and quantitative features of randomly existed karsts topography. The authors encourage implementation of a smarter targeted field investigation based on preliminary non-intrusive ground investigation rather than randomly punching holes in the ground. Authors discussed challenges involved in site characterization program. A case for implementing a step wise progressive site investigation incorporating sequential application of geophysical testing with capability of spatial profiling followed by targeted point penetration testing was presented. Based on such ground investigation output an alternative foundation options were considered to avoid possible foundation failure. In the implemented case study, possible loss of support due to occurrence of sinkholes and redundancy factors such as possible failure were taken into design such as provisions of large numbers of smaller shallow foundations and large numbers of smaller size piles instead of using larger capacity foundations. When addressing the random loss of soil / rock support the authors suggested that design should satisfy ultimate state applying redundancy factor rather than try achieving serviceability state to minimize the overall foundation cost.

Paper 1.16a, INSURANCE INDUSTRY PERSPECTIVE ON THE IMPORTANCE ON GEOTECHNICAL EARTHQUAKE ENGINEERING FOR COMMERCIAL STRUCTURES by James Saldaña: This paper provides an overview of the perspective and practices of insurance industry and owners. Commercial earthquake insurers use well defined underwriting guidelines for risk selection. Computer models aid in the risk selection process and also play a key role in the determination of premiums to charge. The commercial property owner is constantly faced with financial decisions. Protection from infrequent catastrophes may not be a top priority for an owner, but failure to be adequately prepared could mean financial ruin, should an event occur. For the insurer, knowing that a commercial structure has had quality geotechnical engineering work done may make the difference between being able to offer coverage or not if the structure has been built on poor soils that would be excluded by underwriting guidelines. If insurance is offered, reliable information about the engineering may reduce the premiums to affordable levels. Often, the building owner never interacts with the insurer, but instead works only through an agent who has contact with the insurers. Communication and sharing of data between all parties help the building owner to be more aware of the benefits of considering geotechnical engineering as a part of their risk management plan because the insurer will be more within sight, and the financial benefits will be more tangible. The data sharing between the building owners and engineers and the insurers can be provided via the creation of a central, online, public database of detailed engineering information by location address. Building owners and risk managers could submit data for their buildings, and engineering firms could submit data for projects they have

completed. The database could eventually become widely used and recognized as a prime source for all to access detailed data.

Paper 1.18a, GEOTECHNICAL INVESTIGATION AT BARRAGE FOR FOUNDATION DESIGN AT NYAMJANG CHHU HYDRO POWER PROJECT, TAWANG, ARUNACHAL PRADESH, INDIA - A CASE STUDY by Ram Bachan Shivali and Rakesh Mahajan: The authors have presented a case study of the project; The Nyamjang Chhu Hydro Electric Project (780 MW), Arunachal Pradesh, India, located in earthquake prone area with MCE and DBE values of 0.288g and 0.197g for an earthquake magnitude of 7.7 (Mercalli Scale). Based on the in-situ permeability, standard penetration tests and Dynamic Core Penetration tests, and laboratory characterization of the samples analysis for liquefaction potential has been conducted. Ground modification by vibro-compaction, by eliminating the possibility of liquefaction due to development of large strains under high porewater pressure, has been recommended for this project. Based on the observed penetration resistance trends, ground modification by resorting to Vibro compaction method has been recommended.

Paper 1.21a, NUMERICAL MODELING AND USE OF SETTLEMENT REDUCING AUGER CAST-IN-PLACE PILES BELOW A MAT FOUNDATION by Swaminathan Srinivasan and Aaron J. Muck: This paper demonstrated application of numerical modeling to optimize Auger Cast-In-Place Piles (ACIP) below mat foundation to minimize settlement to tolerable level. The authors presented a case study on 45-story Great American Tower, the tallest building in Cincinnati, Ohio in USA. They demonstrated the project is an excellent example of the use of technological advances in site characterization and soil-structure methods. During the process of the exploring design options, designers considered mat foundation with large size footings and mat foundation supported by friction piles terminated above competent bedrock were considered. However both of the options were considered not feasible due to excessive total and differential settlement likely to be experienced beyond allowable magnitude of total and differential settlements. Two other options such as H piles foundation, large diameter drilled pier were considered technically feasible. However while former has issue on vibration which could damage adjacent building the later will have excessive over and above of budget and longer duration of construction period which will not meet project schedule. Due to the fact that designers explored the possibility of optimizing ACIP piles installed into the bedrock. Numerical modeling applying FLAC 3 D were used to carry out many sensitivity analyses to find the optimized pile spacing using soil structural interaction approach with Mohr-Coulomb model for granular soil and Can-clay model for lakebed clay and silt. More accurate model parameters were obtained through additional soil investigation using cone penetration (CPT) and pressuremeter testing (PMT). Many pile load test were carried out on ACIP piles with various pile lengths and obtained load-displacement curves which allowed

calibration of soil structure interaction model. It was found that the 45 storey infrastructure was successfully constructed and the monitoring stress/strain development along several piles has shown consistent with modeled predicted results and settlement was managed to keep below allowable total and differential settlements. The approach of applying advanced geotechnical analysis using state of the practice applying finite element modeling was successfully applied in the approach.

Paper 1.22a, PLANNING AND IMPLEMENTATION OF MEGA GEOTECHNICAL ENGINEERING PROJECTS IN SINGAPORE by Myint Win Bo and Arul Arulrajah: The authors have emphasized importance of systematic approach and detailed planning for implementation of mega geotechnical engineering projects through the case history of a mega land reclamation and ground improvement project, Changi East Land Reclamation and Ground Improvement project in Singapore, which continued for one and a half decades, in the Republic of Singapore. This contribution presents importance of detailed geotechnical investigations, for design purpose or decision making for acceptance of the ground improvement works, and usage of a large quantity of geotechnical instrumentation for monitoring the construction process. Authors have opined that the experience gained from the project has been quite useful for developing contract documents, technical and performance specifications for the subsequent projects pertaining to dredging, reclamation and shore protection works, soil improvement works on natural clay, dredged clay and ultra-soft slurry using prefabricated vertical drain and densification of granular fill by various deep compaction techniques.

Paper 1.23a, RECORDED BEDROCK MOTIONS AND SITE EFFECTS EVALUATION IN TEHRAN CITY by Reza Behrou and Mohammad Reza Ghayamghamian: This paper presents the results of theoretical analyses related to the evaluation of seismic effects in Tehran, Iran. To evaluate the site response, the bedrock motions recorded during Firozabad-Kojour (2004) earthquake ( $M_s=6.4$ ) were utilized. One-dimensional equivalent linear analyses were performed for selected geotechnical and geophysical profiles. The results are presented in terms of site response spectrum and site amplification factor, computed in the period ranges 0.1- 0.5 and 0.1- 2.5 s. The comparison of the estimated site response spectra with the suggested one in the Iranian Code shows good agreements between the two. The amplification factors in period ranges of 0.1–0.5s and 0.1–2.5s are considered applicable to the design of typical and generic buildings of the area.

Paper 1.24a, SITE EFFECTS ESTIMATION IN TEHRAN CITY BY USING EMPIRICAL METHODS by Reza Behrou and Mohammad Reza Ghayamghamian: This paper presents the results of site effect assessment in Tehran using empirical methods. The spectral ratio of the horizontal components of sedimentary site to rocky site and horizontal to vertical spectral ratio methods were applied to estimate seismic parameters. For this purpose, the motions recorded at 25

stations during the Changureh-Avaj (2002), Tehran (2003), Firozabad-Kojour (2004) and Kahak-Qom (2007) earthquakes were analyzed. The results are given in terms of site amplification function, site predominant frequency and an appropriate frequency range.

The results from site classification indicate that most part of the city is built on C class soils based on NEHRP site classification system and show a large contribution of site effects on ground motion. The predominant frequency in the southern part of the city was less compared to the northern part, resulting in increased level of damage on short frequency structures, such as high-rise buildings and long spans bridges, in the southern part. To estimate an appropriate frequency range, various frequencies including 0.5-5, 0.5-7, 1-10, 2-10 Hz were scrutinized. Then based on the calculated amplification ratio in each frequency range and recorded peak bedrock acceleration, the peak surface acceleration was estimated. Comparison of the calculated peak surface acceleration with the recorded one in each station shows good agreement between the calculated peak surface acceleration and the recorded one in 0.5-7 Hz frequency range. Therefore, this frequency range is considered suitable for seismic design in the study area

Paper 1.26a, SITE RESPONSE ANALYSIS IN THE STM-M6 INDUSTRIAL AREA OF THE CITY OF CATANIA (ITALY) by Antonio Cavallaro, Antonio Ferraro, Salvatore Grasso and Michele Maugeri: The paper describes a case history of the geotechnical characterization of a seismic site for the re-use of an industrial building for producing solar panels in the industrial area of Catania, Sicily, Italy, which is located in an area prone to high seismic hazard. Author carried out various in-situ and laboratory test to determine the static and dynamic properties of the soil. The study also attempted to evaluate the small strain shear modulus  $G_0$ , and then the shear wave's velocity  $V_s$  by elasticity theory, by means of the empirical correlations based on Cone Penetration Tests (CPT) and Seismic Dilatometer Test (SDMT) results or laboratory results available in literature. Author evaluated the input motion at the conventional bedrock, the ground response analysis, by the 1-D non-linear code EERA at the industrial building site and uses the record of the earthquake occurred in Sicilia on December 13, 1990 with an intensity of 5.4 as a reference. For the evaluation of soil non-linearity in-situ dynamic Down Hole (D-H) & Seismic Dilatometer Test (SDMT) and by laboratory tests RCT (Resonance Column Testing) has been conducted. The maximum value of acceleration at the surface was of 0.42g by the SDMT  $V_s$  profile, higher than that of 0.35g obtained by the D-H profile. Soil amplification was higher for the SDMT  $V_s$  profile than that for D-H profile. Moreover, soil amplification value was higher by the probabilistic approach, rather than obtained by the deterministic approach; because in the later case the input acceleration is bigger and so the non-linearity soil behavior produces a decreasing of soil amplification.

Paper 1.27a, EFFECT OF NEIGHBORING FOOTINGS ON

SINGLE FOOTING SETTLEMENT by Marawan Shahien and Ali Hefdhallah: This paper demonstrated how stress influence from adjacent footing can affect settlement of the footing surrounded by neighbouring footings. A case history that shows the importance of such an effect was presented by reviewing and comparing change in stress influences and settlement of footings with various configured locations such as corner footing, edge footing and footing at the center of building. The study was carried out on four selected buildings such as workshop building, Fire Fighting building, Guard Dormitory building and Gasoline Station building among 28 auxiliary buildings of an Electrical Power plant near Cairo, Egypt. Stratification of the area as well as geotechnical characteristics of underlying soils including compressible layer of clay were determined from a total of 175 boreholes drilled at the site and SPT tests carried out in-situ and laboratory tests such as oedometer tests carried out on the collected samples. Settlement analyses were carried out for each of the project building. In each building, the settlement was calculated under the center of each footing due to the load imposed from the footing and that due to the stresses on the surrounding footings of the structure. In addition, Settlement was computed for the case of single footing without influence of surrounding loaded footings as the case of the common practice in the geotechnical engineering profession. Settlement analysis was carried out by computing a profile of elastic stress increase due to all loaded areas at the foundation level. Settlement at a point is then computed at the foundation level by integrating vertical strains of the layered ground under the footing. The neighboring footings cause the decrease rate of stress dissipation with depth under the footing and therefore increase the depth or zone that is influenced by the surface stress. The increase in stress influence depth involves soft compressible layer. The major influence happens under interior or center footing with the least influence is in the case of corner footing. The results of their analyses suggested that the effect neighboring footings could be important to the extent that necessitates the change of the foundation system from isolated footings to raft foundation in the light of the maximum allowable settlement of each foundation system. Authors reported that the maximum total due to neighbouring footings could be as high as 4 to 5 times compared to isolated footing and differential settlement between adjacent footings considering influence of neighboring footings could reach up to about 1.5 times the settlement computed for individual footings.

Paper 1.28a, GEOTECHNICAL CHALLENGES IN HIGHWAY ENGINEERING IN TWENTY FIRST CENTURY: LESSONS FROM PAST EXPERIENCES AND NEW TECHNOLOGIES by Abdul Aziz Khandker, Jeffrey T. Anagnostou, and P.D. Deo: The paper describes the several geotechnical failures of the highway embankment case studies from various country and their causes of failure due to earthquake, flood, landslide, sinkholes, problematic soil, extreme weather damage etc. The paper also discussed various geotechnical challenges and available & emerging technology that can be used for highway construction. Also identifies



some of the new challenges of today based on presents and past history. These new challenges can be overcome by applying innovative ideas and using modern technology during planning, design and construction stages of highway development. With better and faster methods of analysis, use of new construction materials (e.g., low density fill materials, geo-synthetics, geo-foam, tensors), utilization of new procedures (e.g., soil stabilization, reinforced earth, soil nailing ) and implementation of effective planning, execution and quality control, these challenges can be overcome in an efficient and cost effective manner. The paper also identifies various current geotechnical practices, which may be considered inadequate for modern-day highway design and construction, but have not been updated for decades. Finally author concluded that lessons learned from the past must be compiled and shared so that the researchers and innovators around the world can focus their attention to real life problems and come up with new materials and design techniques available to Road and bridge Engineers, Transportation authorities, planners, designers should understand that each highway project is unique and must be treated accordingly.

#### Session 1b: Application of Case Histories in Education

Paper 1.01b, **ROLE OF CASE HISTORIES IN GEOTECHNICAL ENGINEERING TEACHING AND PRACTICE**, by R. Shivashankar: This paper describes the experiences on geotechnical engineering teaching in the National Institute of Technology Karnataka (Surathkal). At the author's institute, where a post-graduate and doctoral programme in geotechnical engineering are being successfully run for the past two decades, some of his experiences in effectively teaching geotechnical engineering subjects are being explained in the paper, with the help of a number of case histories on geopractices.

Analyses and designs are being taught in the class rooms at both undergraduate and postgraduate levels for geotechnical engineering students. In order to make the courses more interesting to the students, use of modern methods of teaching and learning aids such as PowerPoint slides, visits to construction projects, case studies, softwares, colloquiums etc. are being tried. These methods help the students to understand the complex concepts better, appreciate the difficulties involved at site, appreciate important projects that are successfully accomplished, analyze the causes of failures and learn important lessons from the failures i.e. the knowledge gained by analyzing the failures help us to evolve a better design methodology and increase our confidence in our designs, inculcate problem solving skills, exercise better judgment in choosing appropriate geotechnical parameters in designs etc. The expertise and confidence in designing and teaching, comes through a lot of exposure to actual field problems. It is rightly said that "Geotechnical engineering is a science, but its practice is an art".

Paper 1.02b, **ON BECOMING A 21ST CENTURY ENGINEERING EDUCATOR: BUILDING COMPETENCIES AND ACQUIRING NEEDED SKILLS** by

Waddah Akili: The paper specifies the potential development of the engineering educator by focusing on the cognitive processes that faculty, i.e. junior engineering educators, most likely follow as they get immersed in teaching. The engineering profession is facing challenges which require according to the author an optimization of teaching, which in turn requires engineering faculty and decision makers to think about teaching and learning in more scholarly ways. The education has to insure that future engineers have the capabilities and skills to perform well in a world driven by rapid technological advancements and diminishing resources. The paper argues that the institution's role is paramount in initiating and sustaining change on becoming a 21<sup>st</sup> century engineering educator. An outline of ways to effective professional development of faculty, to enable them to assume the roles they are entrusted with is presented. Furthermore, a new way to think about the development of the professional engineering educator is proposed. Here, the paper focuses on: (i) the cognitive processes that faculty would tend to follow as they learn more about teaching, (ii) the discipline-based industrial/practical experience they need to acquire to add to their repertoire as "practitioners", and (iii) the institutional initiatives, including: administrative support, and resources. When the engineering institutions mount these presented strategically important initiatives, leading to effective professional development of the engineering educator; then future generations of engineering students would have a better and more relevant education which provides them with the knowledge and skills they need to tackle the complex engineering problems that they are likely to face in the future.

Paper 1.03b, **ENHANCEMENT OF ENGINEERING EDUCATION IN THE ARAB STATES THROUGH COOPERATIVE LEARNING PROTOCOLS** by Waddah Akili: This paper focuses on classroom-based pedagogies of engagement, and cooperative learning strategies in particular and quotes at the beginning "to teach is to engage students in learning". The paper provides an overview of relevant benchmarks of engineering education in the Region of Arab Gulf States. Then, relates author's preliminary findings on teaching/learning practices in Region's colleges, sheds light on the pros and cons of the lecture format, and examines the literature on substance of different active learning protocols, focusing on cooperative engagement strategies. Next, it identifies barriers to reformation in general, and to the use of modern pedagogical skills in particular. What is necessary to create a change, is for the department or college, to have a comprehensive and feasible set of plans: articulated expectations, opportunities for faculty to learn about new pedagogies, and an equitable reward system. The Author reclaims the well-known problem that teaching is undervalued in comparison to research. The paper focuses on proper delivery of engineering courses, including geotechnical engineering subjects. Also, argues that institutional support is of paramount importance in moving the process forward.

Paper 1.04b, **AN EXAMPLE OF TEACHING SLOPE STABILITY FROM TRUE CASE HISTORIES**, by Diego Lo

Presti: This paper describes the intrinsic advantages and possible drawbacks of inductive teaching approach in classroom. More specifically, the paper illustrates an example of teaching the class of “slope stability” based on such methodology. The class takes place at the University of Pisa in the second tier degree of Civil Engineering of Infrastructures and the class has been attended by 40 students in the period October 2010 – January 2011. The inductive teaching approach is very popular in the British/American Higher Education system. On the contrary it is not so popular in Latin countries like Italy. Also, this paper provides comprehensive information on the Higher Education system in Europe and specifically in Italy.

On the basis of the personal experience of the author, the following positive aspects obtainable by the use of true case histories; e.g., to stimulate passion and interest of students in the subject matter; to facilitate the understanding of student independently of her/his own background; to facilitate the learning process of general concepts; and to allow brilliant students to develop a deeper insight without penalizing less brilliant students etc. Also, the main risk of the above outlined approach is that students end up with a mere mechanical application of rules without a clear understanding of what they are doing.

Paper 1.05b, CASE HISTORIES IN GEOTECHNICAL ENGINEERING EDUCATION, by James Mahar: This paper describes as case histories can be taught as an individual course or as part of a specific engineering class. These studies are very important when the teaching methodology incorporates the observational approach in design and construction. Several resources for case histories are available. However the most insightful are those in which the instructor has personal knowledge or the student participates in a case history-type project. In February 2012, the State of Idaho closed Colonial Hall on the campus of Idaho State University. The justification was a potential life safety issue based on an engineering report in which the investigators postulated that the existing damage in the building may cause collapse during a strong but non specified earthquake. This decision by the State provided an excellent opportunity to teach the geotechnical design process using a case history on campus as part of an advanced course in Foundation Engineering. In addition, it provided an excellent means for the students to obtain actual experience in performing a foundation engineering investigation and to be accountable for providing data to the design professional responsible for evaluating the structural integrity of the building.

The students under the supervision of the instructor collected the available geotechnical data, performed subsurface investigations, made damage observations, carried out laboratory tests, analyzed the building settlement/structural deformation and prepared a geotechnical report outline. Strategies for mitigating further settlement were developed in the course. The students were required to sign the documents which were submitted to the structural engineer responsible

for the building assessment.

Paper 1.06b, CASE STUDIES – PAVEMENT OF THE EDUCATOR’ ROAD, by Richard Ray, Peter Scharle, and Robert Szepesházi: This paper describes the usefulness of Geotechnical triangle developed by Burland to inspire the students’ motivation by telling them how the geotechnical triangle thinks and why is it worth attaining. The extension of this simplex i.e., triangle to a tetrahedron brings into the framework the construction technology, equivalent of importance with ground profile, observed behavior and appropriate model. The case histories retain their central role within this 3D simplex. In this perspective, authors describes geo-engineering proves to be analogous with medicine where concepts such as symptom, syndrome, diagnose and therapy appear and case histories in teaching have a central role, as well. This role has got an institutionalized representation in Eurocode 7, the new standard for geotechnical design brought into force in the EU by 2010. Burland-triangles served well in responding the challenge of understanding the philosophy of the whole system of structural standards (Eurocode 0 and 1) and the differences specifying the geotechnical subsystem (Eurocode 7). Case histories deserve the central place occupied in the Burland simplices. They incorporate the interdependence between the vertices; let these connections be relating to any goal, task or reason in geo-engineering activity.

Paper 1.07b, GEOSYNTHETIC REINFORCED SEGMENTAL RETAINING WALL FAILURE: FORENSIC INVESTIGATION AND REMEDIATION by Rajaram Janardhanam and Miguel A. Pando: This paper presents a retaining wall failure case history to cover the different modes of failure of retaining wall and to highlight the importance of global stability failure. Specifically, this case study of a mechanically stabilized earth (MSE) wall has been used by the authors in undergraduate and graduate courses of geotechnical engineering to highlight the importance to include in the design process the assessment of global stability. The project is valuable to students due to wealth of data including field and laboratory site investigation, monitoring data from slope inclinometers, amongst other data. The incorporation of the failure case study into the course consists of three lectures. First the initial design information including wall height, backfill information, geosynthetic reinforcement type and layout, etc. is presented. The first assignment requires students to check conventional internal and external stability. In the second lecture post failure photos of the wall are presented. The failure incident is discussed in detail and the students are then asked to take a second closer look of the project information to try to explain the failure. This time around they also have access to the post failure inclinometer data and field reports that included evidence of surface cracks on the pavement built on the top of the wall. With this available information students successfully explain the failure mode via global slope stability analyses within another assignment. The authors report very positive feedback from students about the presentation of a failure case study followed by discussions in the classroom. Furthermore, students also expressed wanting

to see more such case histories of failure of geotechnical structures, forensic investigation demonstration and remediation measures presented in all their geotechnical engineering design courses. The human psychology component in the author's point of view enhances the learning of students when they actually see the failure of a structure and tie this to the relevant technical content. The resulting better understanding of the subject matter translates into a better "learning outcome". The authors offer interested faculty to request detailed material on this case history beyond what is presented in the paper.

Paper 1.09b, **STUDENTS AS FORENSIC ENGINEERS: AN INNOVATIVE APPROACH TO TEACHING SOIL MECHANICS** by Benoît Courcelles, Lina Forest and Anastassis Kozanitis: The paper presents the study of failure case studies from a forensic point of view which challenges students with real world multidisciplinary applications. In the reported approach students are thus entirely involved in the case study and act as investigators recruited to find the cause of a failure and its impact on social and environmental issues. This methodology prevents student passivity and the role of the professor is only to guide students towards a holistic understanding of the events, rather than suggesting solutions for them. The originality of this paper is the inclusion of a failure case study into the curriculum of a soil mechanics lecture with 12 three hour long lectures, 7 laboratories and 12 recitation classes. The topics of the soil mechanics lecture are shown to be linked to a real civil engineering case study to illustrate the implication of engineering activities. This new approach received funding from the Centre of teaching in the summer of 2012. The paper describes in detail the overall course design and outline, from the selection of the failure case study to its implementation into the curriculum. As failure case study the Teton dam case study was implemented into the soil mechanics class. The Teton dam was located in the southeast of Idaho, USA and is unfortunately known as the highest embankment dam that had ever failed in the history of earth dams. The history of Teton dam and its failure in 1976 is described with additional information about the hydrogeology and investigations after the failure. The authors present for two topics of the soil mechanics class the use of the failure case study in detail, which are classification of soil and compaction. Furthermore, the benefits of this enhanced education based on real applications which are able to visualize the learning objectives of the class are demonstrated with excerpts of the interactive discussion between students and faculty. This approach stimulates self-reflection of students and reinforces their conception of responsibilities in their future profession. This methodology is presently testing in the course of soil mechanics at Polytechnique Montreal and future works related to this new approach will consist in an evaluation of the course at the end of the present fall 2012 session.

Paper 1.10b, **USING LOCAL CASE HISTORIES IN UNDERGRADUATE TEACHING**, by Andrew T. Rose: This paper describes as local geotechnical case histories provide

examples of the types of geotechnical problems typical in an area. One of the challenges of civil engineering practice in central and western Pennsylvania, as well as neighboring states is the variety of geotechnical problems encountered when trying to develop or improve a given site. Slope stability issues, mine subsidence, expansive soils and slag fills, and karst landforms are some of the more common geotechnical problems that might be encountered at a given site. While undergraduate courses and supporting textbooks generally cover the basic principles of geotechnical engineering, time and reference materials necessary to cover some of the specific geotechnical problems commonly encountered in local professional practice are often not available. The end result is that graduates are exposed to the basics of geotechnical engineering with little appreciation of how the principles are applied in local engineering practice. To help improve undergraduate students' understanding of the breadth and challenges of geotechnical engineering projects in the local area, an oral presentation assignment was implemented using local case histories published in the literature. Student teams presented to the class a summary of their assigned case history. A survey assessed the effectiveness of the assignment, gathered student perceptions of the benefits of the activity and solicited suggestions for improvement.

Paper 1.11b, **USING THE 1911 AUSTIN DAM FAILURE CASE HISTORY IN UNDERGRADUATE TEACHING**, by Andrew T. Rose: This paper describes the failure of a concrete gravity dam located north of the town of Austin, Pennsylvania on September 30, 1911. The paper provides an interesting case history for undergraduate students of civil engineering. The mistakes of the various parties involved are easily understood. The analysis of the dam for both sliding and overturning is easily incorporated and discussed by entry level students and provides exposure to a number of technical as well as non-technical issues that are an integral part of the undergraduate curriculum. Also the economic aspects of the dam's design and construction, the social issues involving relief efforts, the contemporary national media coverage, as well as the ethical and legal aspects of the dam's failure addresses other program outcomes.

Paper 1.12b, **THE INITIATIVE OF THE HELLENIC SOCIETY FOR SOIL MECHANICS AND GEOTECHNICAL ENGINEERING TO SUPPORT THE DEVELOPMENT OF CASE STUDIES SUITABLE FOR INSTRUCTION & A SLOPE STABILITY EXAMPLE** by George Belokas, George Dounias, Marina Pantazidou, and Christos Tsatsanifos: The paper calls for fully documented reports of case studies to achieve benefits for educating students and geotechnical engineers as well. The Hellenic Society for Soil Mechanics and Geotechnical Engineering (HSSMGE) in Greece is proposing a way of supporting development of such cases through incentives. Furthermore, the authors are providing an example of a suitable case study in form of a fictionalized narrative related to the design and construction of highway earthworks in Greece and discusses alternative ways in which the case material can be used in

instruction. The support structure proposed is the initiative of the HSSMGE to establish a competition for case studies appropriate for geotechnical instruction and award a prize at its Geotechnical Conference. The paper includes the evaluation criteria and case study specifications of the competition, which highlight the characteristics of case study material suitable for use in instruction. The evaluation of case studies is based on the suitability for geotechnical engineering courses taught in Greek Civil Engineering Departments, preferably belonging in the 5-year integrated undergraduate curriculum and the development of the case study should correspond to specific learning outcomes. Furthermore, the supporting material of the case study should be available in an electronic format. The authors explain the evaluation criteria with the aid of the following questions: (a) Does the case highlight in a paradigmatic way the application of a theory, principle or technique taught in geotechnical engineering courses? (b) Does the case stress a problem important for practice? (c) Is the case and supplementary material rich and complete and are they adequately annotated with explanations? The paper provides essentials for the content of case studies and how they can be used for geotechnical engineering courses. The learning outcomes that can be achieved depend on how the case is used. If the case is presented as a technical narrative, without students performing any work on the own, a suitable learning outcome is “be aware of the professional responsibilities pertaining to geotechnical projects”. Alternatively, the case may be presented in parts and students asked to perform some analyses on their own. The authors distinguish here two parts. Part I is appropriate even for an introductory geotechnical course, whereas Parts I and II together are suitable for more advanced courses. For the active involvement option, achievable learning outcomes include “identify potential modes of failure” and “apply methods of analysis already covered in course”. The presented case study refers to slope stability analysis of highway earthworks. In Part I is the case study described and all information for the requested slope stability analysis is provided. Furthermore, results for the slope stability analysis are given with factor of safeties to enable a validation of the analysis which has to be performed by the students. In Part II the students are asked to perform a modified slope stability analysis considering possible kinematic sliding mechanisms with a translational slip surface instead of the rotational slip surface which had to be analyzed in Part I. The definition of the slip surface is explained with the geological site conditions and the analysis is described to be explained at another section. Here, the results of the analysis in terms of the mobilized shear strength assuming a factor of safety equal to 1 due to observed deformations of the slope are provided as well. The case study is extended with another task for the students to solve which is the feasibility analysis of excavation as a repair alternative. The third task includes variation of pore water conditions and their influences on slope stability. The slope failure presented herein as an example of a case study suitable for instruction underscores the usefulness of case studies with its ultimate “lesson learned”. The challenge of the geotechnical engineer is often two-fold: not only to identify

the potential for the instability of the larger area (at the stage of earthwork construction, in this particular case), but also to make a convincing argument (in the absence of conclusive evidence) that additional investigation is warranted, incurring additional costs and delays.

Paper 1.14b, “EXTREME FOUNDATIONS” FOR PEAT DEPOSITS: CONCEPTUAL MODEL, CREATIVE THINKING AND LEARNING PROCESS by Chee-Ming Chan: This paper describes the problem based learning approach for Advanced Foundation Engineering course to design the foundation in highly problematic peat soil. With this approach students were able to think logically and critically in the conceptualization of a real life engineering problem and formulation of an innovative solution. The author noticed that the problem based learning approach helped to enhance the students’ soft skills like communication, teamwork, leadership, business knowledge, entrepreneurship and project management; often overlooked in the delivery of geo-engineering courses. These soft or humanistic skills are also evaluated as a part of exit survey. The embedded problem-based project has shown encouraging results in terms of projected PEO-PLO and HS achievements. Analysis of results from the exit survey displayed the students’ ability to work collaboratively in groups with moderate facilitation, not supervision, on the lecturer’s part.

Paper 1.15b, CASE STUDIES USED IN INSTRUCTION TO ACHIEVE SPECIFIC LEARNING OUTCOMES: THE CASE OF THE EMBANKMENTS CONSTRUCTED FOR THE APPROACH TO LIMERICK TUNNEL, IRELAND, by Orr and Pantazidou: When instructors wish to use a case study for general purposes, they have many choices. However, when they intend to use cases to achieve specific higher level learning outcomes (i.e. past the “recall” level), the case study must be written with this specific goal in mind, in order to allow active involvement of the students with the case material.

This paper gives an example of a case study written for instructional purposes, in order to support the achievement of specific learning outcomes which include identifying modes of failure and selecting appropriate soil parameter types and values. Case writing was based primarily on information from a detailed publicly available article, supplemented with additional input from one author of this article. The case narrative is accompanied by annotated calculations, which follow the general design philosophy of the project. The case focuses on two of the main issues for the geotechnical design of the highway embankments close to the Limerick Tunnel, which are founded on very soft organic fine grained material. First, secondary compression, which is sizeable for a highway project, required surcharging to reduce the rate of long-term settlement. Second, the low undrained shear strength and high compressibility of the foundation material required construction of the embankments in stages, to achieve a degree of consolidation necessary for increased effective stress, increased shear strength and reduced compressibility. This paper includes the case narrative, excerpts from the

accompanying calculations, and comments on the instructional decisions involved in the preparation of both.

#### Session 1c: Observational Method, Successes and Failures

Paper 1.01c, A NON-LINEAR METHOD TO ESTIMATE ELASTIC SETTLEMENT OF SHALLOW FOUNDATIONS USING SMALL-STRAIN STIFFNESS, by Reza Amini Ahidashti, Abdolhosain Hadad: This paper describes a non-linear method for the estimation of elastic settlement of shallow foundations on granular soils by using small strain stiffness. The study explores the use of the surface-wave seismic methods, specifically the SASW and CSW methods, to predict immediate settlement. This method can be effectively used to predict the settlement of footing on granular soils and it is more accurate than the SPT or CPT based predictions. To validate the method, results of the survey of loading tests of three sites were evaluated and compared to the measured results by presenting a series of load displacement curves. Appropriate coincidence between the result of loading test and predicted settlement, indicated the accuracy of proposed method. Predictions based on in situ parameters from seismic measurements were observed closer to measured settlement under service loads.

Paper 1.02cR, PERFORMANCE OF DIGBOI REFINERY MODERNIZATION PROJECT FROM GEOTECHNICAL ASPECTS - INVESTIGATION AND OBSERVATIONS, by Gokul K. Bayan: This paper describes geotechnical investigations performed in support of a major modernization project at the world's oldest operating oil refinery. The Digboi Refinery, located in the North East Region of India, had been in operation for more than one hundred years when geotechnical explorations were begun in 1987 to ascertain the subsurface conditions and develop recommendations for design and construction of new structures. The investigations were carried out in three phases, the first involving borings up to 12 meters in depth, the second borings up to 25 meters in depth, and the third borings up to 21 meters in depth. The explorations encountered strata chiefly consisting of low- to medium-plasticity fine-grained soil and non-plastic silty sand, with occasional soft zones and organic matter. A variety of field tests were performed, including standard penetration and cone penetrometer tests. Laboratory work included index and strength testing as well as a wide array of chemical testing. Recommendations were provided for various structures and foundation types, and consideration was given to mitigating the effects of soils susceptible to liquefaction. A particular challenge involved the construction of large oil storage tanks, for which differential settlements had to be tightly controlled. The extensive investigation program and comprehensive recommendations contributed to the success of the modernization project.

Paper 1.03c, APPLICATION OF OBSERVATIONAL METHOD IN THE SUCCESSFUL CONSTRUCTION OF UNDERGROUND STRUCTURES, SARDAR SAROVAR

(NARMADA) PROJECT, GUJARAT, INDIA, by Indra Prakash: This paper presents a case study in the application of the observational method to identify and address problems encountered in rock excavation and tunneling. The Sardar Saravar (Narmada) hydroelectric project is located in Gujarat State, India. A 23-meter-wide, 57-meter-high, 212-meter long powerhouse and associated tunnels were excavated in rock downstream of the dam using the New Austrian Tunneling Method. The design of the initial rock supports was based on the expected favorable rock mass conditions. As the excavations progressed, visual indications of distress including rock falls and shotcrete cracks were observed, and instrument readings were taken to monitor rock movements. Further investigations revealed that the distress was not superficial, but indicated larger problems with the rock support systems. Through field testing and back-analysis, including conventional methods and finite element analyses, it was determined that the rock mass conditions were less favorable than indicated by the preliminary explorations, and therefore initial rock bolt design was not adequate to restrain the rock and prevent the development of cracks. Longer pre-tensioned rock bolts and cables were designed and installed to provide the required support, rib supports were provided in the tunnels, and grouting was performed to stabilize the rock mass. This case study demonstrates the value of the observational method in identifying and reacting to unforeseen subsurface conditions.

Paper 1.04c, BRACED SHEET PILE SHORING WALL IN SENSITIVE CLAY, by Yadav Pathak, Brian Hall, Marc Sabourin, Jake Brucker: This paper describes a case history on the design and performance of a temporary braced sheet pile shoring wall constructed within the median between heavily-trafficked lanes of the Trans Canada Highway in Langley near Vancouver, British Columbia, Canada. The paper discusses the bulkhead face stability issues caused by soft, high plasticity, sensitive glaciomarine clay and running sand. The excavation extended to 9.7 m depth below the existing road grade into glaciomarine clay which is known for the stability problems of excavation and foundation settlement. In the present study geotechnical monitoring responses were compared with the predicted performance. Undrained conditions governing the design were discussed. The design analyses included a nominal surcharge pressure of 16 kPa to account for highway traffic behind the headwall sheet piles. Water reactive polyurethane grout improved the mechanical behaviour of the clay sufficiently to stabilize the exposed bulkhead cut face. The limit equilibrium method was used to check the global stability.

Paper 1.05c, CASE STUDY: APPLICATION OF THE OBSERVATIONAL METHOD USING HIGH STRAIN DYNAMIC TESTS, by Adolfo C. Caicedo-Aspiazu and Nelson Caicedo: This paper provides an overview of the technology of high-strain dynamic testing (HSDT) of piles and reviews a case study involving HSDT used in conjunction with the observational method. HSDT is based on the principle that a pile will react to hammer or drop weight

impact as a function of the physical properties of the pile and the resistance of the surrounding soil. Equipment required to perform HSDT includes the pile driving analyzer, accelerometers, and strain gauges. Pile capacity can be deduced from HSDT using the theoretical principles of engineering mechanics and empirical correlations. Dynamic testing can also be used to detect and evaluate pile structural damage. HSDT was used to facilitate the observational method in the construction of driven pile foundations for the Bahia-San Vicente Bridge in Ecuador. The soil profile consisted of loose sandy silt overlying stiff clay overlying weathered rock and bedrock at a depth of approximately 70 meters. The project was located in a seismically active region, and liquefaction of the sandy silt layer was a design consideration. In order to attain a safe and economically efficient foundation design, dynamic testing was performed on selected piles in each bridge pier. The HSDT results were evaluated and the pile depths were optimized to achieve the design objectives.

Paper 1.08c, IMPORTANCE OF OBSERVATIONAL METHOD IN VIEW OF NUMERICAL ANALYSES FOR RETAINING STRUCTURES IN SOFT SOILS by Patrick Becker: This paper discusses the importance of the observational method and limitations of numerical analysis based on a case history of an 8m deep excavation for retaining structures in soft soils located in the City Constance in southern Germany. The excavation was monitored with the help of instruments and structure was successfully constructed in deep soft lacustrine clay deposits in 2008. The observational method included measurements and evaluation of the soil-structure-interaction. The measuring intervals, duration between the measurement and the evaluation of the observations have to be adjusted as per the progress of construction and as per the developments in the behavior of the soil-structure-interaction. Numerical analyses can be a powerful tool for predicting the stress path and time dependent deformation behavior of retaining structures in soft soils. But the quality of these numerical analyses is directly linked to the quality of input parameters, the suitability of the constitutive models and the ability of geotechnical engineers. In general the observational method has to be adopted in cases where it is not possible to predict the soil-structure-interaction based solely on previous ground investigations and geotechnical predictions.

Paper 1.10c, NETWORKED GEOTECHNICAL NEAR REAL-TIME MONITORING FOR LARGE URBAN EXCAVATION USING MULTIPLE WIRELESS SENSORS by Stephen M. McLandrich, Youssef M.A. Hashash, Nick J. O'Riordan: This paper describes the importance of using multiple sensors and sophisticated geotechnical network monitoring system to assess the movement of the ground (horizontal as well as vertical) due to large excavation. During construction, a fully-automated real-time digital geotechnical monitoring system called the Global Analyzer is used to track the performance of the excavation of downtown portion of the SOMA district in San Francisco, California, for the

transportation facility Transbay Transit Center (TTC). The excavation is approximately 1,500 feet long by 180 feet wide and ranges from 55 to 65 feet deep. The Global Analyzer is a key tool in supporting an efficient decision process informed by more complete and timely performance data. Instrumentation used for monitoring the excavation process includes inclinometers, deep settlement markers, extensometers, piezometers, and an automated total station network. Author noticed that the data management and distribution web-portal has proven to be a helpful and efficient tool in assessment of the excavation performance. Also, the inter-disciplinary efforts between the geotechnical engineer and the software programmers are important to improve the capabilities and wider use of this data management and distribution tool. Finally, a geotechnical monitoring system is only as beneficial as the collaborative decision making process and execution of decisions of the greater excavation team.

Paper 1.12c, A COMPARISON OF THREE AND TWO-DIMENSIONAL ANALYSES OF ROCKFILL DAMS IN NARROW VALLEYS (A CASE STUDY: THE VANYAR DAM) by Mehdi Derakhshandi, Mojtaba Honarmand and Amir Hossein Sadeghpour: This paper discusses results of three and two dimensional numerical analyses of the Vanyar dam located in narrow valley in terms of settlement, pore water pressure, and total vertical stress. These analyses were carried out by a finite difference method through FLAC-3D and FLAC-2D software. The settlement data recorded by the instruments in the body of the dam are compared with the numerical analyses. The main objective of this study is evaluation of the effects of two and three dimensional numerical analyses on the behavior of Vanyar dam at the end of construction. The instrumentation data extracted from monitoring system have been used to verify the results of numerical analysis. In the upper half of the dam, the results of the three and two-dimensional analyses are near each other. In the lower half of the dam, the two dimensional numerical analysis predicts the settlements more than those obtained from the three-dimensional analysis. This is due to the lack of plane strain conditions caused by the specific geometry of narrow valleys. The two-dimensional numerical analysis predicts the total vertical stresses more than those predicted by the three-dimensional numerical analysis. The study shows that the assumptions made in the numerical models about the material properties are consistent with reality.

Paper 1.14c, USE OF THE OBSERVATIONAL METHOD TO VERIFY DESIGN OF EARTH RETENTION STRUCTURES, by Timothy H. Bedenis and Christopher G. Nadia: This paper presents two case studies that illustrate the use of instrumentation to confirm design assumptions and ensure the satisfactory performance of earth retention systems. The first case study involved the expansion of a slip in Bay City, Michigan to accommodate bulk freighters and permit the stockpiling of offloaded aggregate adjacent to the slip. The design consisted of a driven steel sheet pile bulkhead with a single row of horizontal tie rods anchored by deadmen. Slope inclinometers were installed to measure the deflection of the

bulkhead wall under the effects of test stockpiles. The inclinometer measurements were used to adjust the original design analyses, evaluate the stresses in the structural components, and verify the stability of the bulkhead. The second case study involved a deep braced excavation in Dearborn, Michigan that extended into soft clay, with the attendant basal heave issues. A king pile system was used to span from the bottom level of pipe struts to competent till, resisting basal heave forces. The pipe struts were instrumented with strain gages to measure the bracing loads. The measured loads correlated well with the loads calculated in design, confirming the methods of analysis and verifying the adequacy of the bracing system.

Paper 1.15c, CASE HISTORY - PERFORMANCE MONITORING SUCCESS by Charles B. Grant, Tom Hurley: This paper describes the contribution of performance monitoring to the success of a large-scale urban redevelopment project. The City Creek Center project in Salt Lake City, Utah, involved deep excavations immediately adjacent to occupied buildings on shallow foundations. Excavation support systems included soil nail walls and anchored diaphragm walls, with micropile underpinning of selected structures. Movement of the excavation support systems and adjacent structures was monitored using conventional optical surveys, inclinometers, and automated survey methods. The performance monitoring systems detected unusual movement of a diaphragm wall adjacent to a 25-story building during one stage of the excavation. A stabilizing berm was placed in front of the diaphragm wall as an emergency measure to arrest the movement. Additional explorations were performed, identifying unanticipated subsurface conditions. A remedial design was implemented, involving additional soil anchors and subgrade concrete struts. The performance monitoring system played a crucial role in this project by preventing damage to adjacent structures and helping the contractor minimize schedule impacts.

Paper 1.17c, DESIGN OF SHALLOW FOUNDATIONS FOR A LARGE POLYSILICON PLANT IN CHINA by Kul Bhushan, Ken Choudhary: The paper discusses development of a shallow foundation system consisting of mat foundations for support of all structures including heavily loaded, settlement sensitive structures at recently completed Polysilicon Plant in China. The mat foundations traversed variable soil conditions consisting of deep fill, residual soils, and bedrock. Measurements of settlement were made during construction of major structures and tanks and these values compared favourably with predicted settlements. This case history describes the use of surcharge to reduce settlements of stiff soils and compacted fills though it is generally used for improving soft soils. CPT data was used to locate the weak/soft zones present at the boundary of the residual soils and bedrock. These weak zones were also improved by surcharge. The use of shallow foundations resulted in significant savings in cost as compared to pile foundations.

Paper 1.19c, SUPPORTING TUNNELLING EXCAVATION OF AN UNSTABLE SLOPE BY LONG TERM DISPLACEMENT MONITORING, by Francesca Bozzano, Paolo Mazzanti and Alberto Prestininizi: This paper presents a case history involving the use of performance monitoring systems to detect, evaluate, predict, and avoid landslides. A highway tunnel in Italy was to be constructed into a hillside susceptible to landslides. After small landslides affected preliminary phases of the construction work, a monitoring network including slope inclinometers, piezometers, anchor load cells, optical survey prisms, and a remote displacement monitoring system known as a Terrestrial SAR Interferometer was established at the tunnel site. The system was designed to have redundant monitoring capabilities to provide confirmation of measured displacements and backup for the various sensors. Real-time detection and reporting was essential to the use of the network to support project-level decision-making. The monitoring network was used in three general phases of activities. First, movements detected by the monitoring network informed the design of stabilization measures. Second, monitoring was used to evaluate the effectiveness and safety of installed stabilization measures. Finally, the monitoring system facilitated measurement of the effect of tunneling activities on the landslides and stabilization measures, allowing active management of the construction process to avoid damaging landslides and ensure safety.

Paper 1.20C, DETERMINATION OF IN-SITU STRESS AT DESILTING CHAMBER OF PUNATSANGCHHU HYDROELECTRIC PROJECT (BHUTAN), TO RECONFIRM ITS ORIENTATION INFLUENCED BY TOPOGRAPHY- A CASE STUDY by D.S. Subrahmanyam, S Sengupta, R K Sinha and G Shyam: This paper discusses the finalization of orientation of desilting chamber of Punatsangchhu Hydroelectric Project stage-I in Wangdue-Phodrang district of Bhutan based on the in-situ stress measurements by hydro fracture tests. National Institute of Rock Mechanics, India carried out stress measurements at RD 100m and RD 150m inside an exploratory drift approaching towards desilting chamber with a rock cover of 100m. This test was required to freeze the orientation of desilting chamber vis. a vis. orientation of maximum compression (H) which was found to be N 150. As it was only 100 to 150 m away from the portal, a topography effect on the orientation of (H) was also studied. The stress orientation evaluated at RD 360m reconfirms the orientations revealed from earlier stress measurements at RD 100 and RD 150m. Accordingly, direction of desilting chamber was frozen along N 150 degree. The study also confirms that the earlier stress measurement results do not suffer from topography related influence. Plane and Gensim programmes were used in the analyses.

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