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General Report - Session 3

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Commemorate the Legacy of Ralph B. Peck
April 29 - May 4, 2013 CHICAGO
Seventh International Conference on
Case Histories in Geotechnical Engineering
and Symposium in Honor of Clyde Baker

GENERAL REPORT - SESSION 3

3a. Failure and Remediation of Slopes, Dams, Embankments and Landfills

3b. Failure and Remediation of Retaining Structures, Slurry Walls, and Deep Excavations, Dewatering, Stability

3c. Improving the Stability and Maintenance of Monuments

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INTRODUCTION

This General Report summarizes the 84 papers accepted for the Session 3 focused on:

- 3a. Case Histories on Failure and Remediation of Slopes, Dams, Embankments and Landfills (53 papers),
- 3b. Case Histories on Failure and Remediation of Retaining Structures, Slurry Walls, and Deep Excavations, Dewatering, Stability (27 papers),
- 3c. Improving the Stability and Maintenance of Monuments (4 papers).

The papers originate from 26 countries (11 European countries, 3 American countries, 11 Asian countries and 1 African country). The papers cover a number of relevant topics divided into three different sub - sessions. As for the two papers included in Session 3c, only one deals with maintenance and retrofit of historical monuments. Indeed paper 3.03c is more pertinent to session 3b. On the other hand some papers included in Session 3a could also be considered in Session 3b and vice versa.

Session 3a

Paper	**Origin**	**First Author**	**Topic**
3.01a	India	Kamal Dev Ralh	Interference between landslides and infrastructures
3.02a	India	Kamal Dev Ralh	Interference between landslides and infrastructures
3.03a	India	R.P. Sharma	Earth dam (failures)
3.04a	Japan	Deping Guo	Landslides (seismically induced)
3.05a	USA	Wesley Schmutzler	Levee embankments (foundation consolidation by deep mixing method)
3.07a	USA	Randa Asmar	Earth dam (seismic retrofit)
3.08a	Vietnam	Nguyen Minh Hai	Embankment (failure)
3.09a	USA	Anagnostou, Jeffrey	Interference between landslides and infrastructures
3.10a	Greece	Konstanina Papadopoulou	Landslide (back – analyses of failures)
3.13a	Iran	Maryam Mahdizadeh	Earth dam (natural period)
3.14a	Hungary	David Turi	Earth dam (reservoir failure)
3.15a	Colombia	Gilberto Rodriguez	Landslide (volcanic ashes)
3.16a	USA	Peter A. Dickson	Concrete – rock fill dam (design and fault movement)
3.18a	USA	Scott Newhouse	Earth dam (failure by erosion)
3.20a	USA	Aravinda Ramakrishna	Road Embankment construction on reinforced soil
3.21a	Colombia	J. P. Villada Rodas	Landslides (residual soil)
3.24a	Japan	R. Rasouli	Landslides (deep soil mixing for mitigation of liquefaction induced lateral displacement)
3.25a	Saudi Arabia	Bahaaeldin Sadagah	Landslides (rock slopes)
3.26a	India	Gokul K. Bayan	Landslide (factory of safety for slopes potentially subject to flow failure)
3.27a	Iran	Fardin Jafarzadeh	Rock fill dam (consolidation and compaction grouting)
3.28a	Iran	Reza Ziaie Moayed	Freeze – thaw cycle effects on CBR of stabilised soil
3.29a	The Netherlands	V.M. van Beek	Levee embankments (backward erosion piping)
3.30a	Italy	B. Cosanti	Levee embankments (characterization of old embankments)
3.31a	USA	G. Chow	Earth dam (Historical summary and introduction of two projects)
3.32a	Iran	V.M. van Beek	Retaining wall (2D modelling of underground Metro station)
3.33a	Iran	A. Mohammadi	Slope stability (analyses and effects on Water Conveyance tunnel)
3.34a	USA	Swaminathan Srinivasan	Slope stabilization
3.36a	USA	H. Fallah	Rock fill dam with concrete facing (static and seismic evaluation)
3.38a	USA	Michael J. Thelen,	Slope stabilization
3.39a	USA	W. ken Beck	Slope stabilization
3.40a	USA	D. B. Northdurft	Deep Excavation (works in rock, by blasting, for underground parking, failure and remedies)
3.41a	Malaysia	Suhaimi Jamaludin	Interference between landslides and infrastructures
3.42a	Slovakia	Miroslav Cerny	Landslide (failure remediation)
3.44a	India	Jaykumar Shukla	Rubble mound breakwater
3.47a	Hungary	József Mecsi	Embankment failure
3.48a	Algeria	Sadaoui Omar	Landslides
3.49a	USA	Lelio H. Mejia,	Rock fill dam (seismic retrofit)
3.50a	India	Janvi Talsaniya	Rubble mound design
3.51a	Greece	Vassilis Houssiadas	Landslide
3.52a	Lebanon	Mansour Neaimeh	Slope stability (static and seismic conditions)
3.56a	India	Kishor Kumar	Landslide
3.57a	Saudi Arabia	Bahaaeldin Sadagah	Interference between landslides and infrastructure(rainfall induced debris flow)

3.60a	Iran	S .A. Naeini,	Landfill (settlement prediction)
3.61a	USA	Mario Mauro	Retaining wall (slurry wall installation)
3.62a	Italy	N. Squeglia	Levee embankments (Stability analyses, remedies)
3.63a	Greece	Eleni Sakoumpenta	Landslide (stabilization)
3.65a	USA	D. Ritzman	Earth dam (Seismic retrofit of embankment)
3.66a	USA	M. Perlea	Levee embankments (Seismic evaluation)
3.67a	USA	Jian Hu	Retaining wall (full scale load test of flood wall, continuous steel sheet)
3.68a	USA	Nien-Yin Chang	Earth dam (1D seismic response analysis)
3.70a	Canada	Alper Turan	Road embankment (interaction between abutment deep foundations and embankment settlements)
3.75a	Turkey	Atila Sezen	Rock fill dam
3.76a	India	Shilpa Pal	Concrete dam (3D DEM analysis of discontinuities)

Session 3b

Paper	**Origin**	**First Author**	**Topic**
3.01b	Hong Kong	John Endicott	Deep excavation failures
3.02b	USA	A. J. Lutenegger	Piles (Helical screw - piles for underpinning residential structure)
3.03b	Canada	A. Sandrekarimi	Retaining wall (Active earth pressure by numerical analyses)
3.04b	Turkey	O. Sevencan	Deep excavation (numerical analyses of a Metro Station)
3.05b	Italy	Alex Sanzeni	Deep excavation (numerical analyses and monitoring)
3.06b	Taiwan	Jeng Ching-Jiang	Tieback supported slope (failure and remedies)
3.07b	USA	Kumars Zand-Parsa	Tieback wall: design method
3.08b	China	L.Tony Chen	Deep excavation (excessive movements of temporary supports and countermeasures)
3.09b	China	Z.H. Xu	Deep excavation in soft soil in urban area
3.11b	Korea	Tae-Seob Kim	Ground anchors (Jacket pack anchors in soft soil)
3.15b	Czech Republic	P. Koudelka	Retaining wall (Scale physical models for active and passive earth pressure)
3.16b	USA	J. G. Bentler	Retaining wall (distress of MSE)
3.17b	USA	F. Clemente	Retaining wall (Failure and restoration of cellular sheet pile structures)
3.18b	Iran	Mohammadreza Abbasi Garavand	Retaining wall (Earthquake induced failures)
3.19b	Iran	S. Mohsen Haeri	Deep excavation (rainfall induced crack)
3.20b	Germany	M. Herten	Retaining wall (failure of wing wall because of hydraulic heave and piping of embankment)
3.21b	Iran	Pooyan Ghasemi	Retaining Wall: (Anchored Quay wall and seismic deformation)
3.22b	USA	D. Bird	Retaining wall (Sheet Pile cell: stabilization works)
3.25b	USA	M. E. Meyer	Retaining wall (Reconstruction of a MSE tired wall, deteriorated by the freeze – taw effects)
3.26b	USA	G. Zelada – Tumialan	Deep Excavation(displacement of existing masonry building)
3.28b	UK	Yuepeng Dong	Deep excavation: (Top – down method 3D numerical analyses)
3.30b	UK	M. Edmondson	Damage of buried tanks
3.32b	India	G.L. Sivakumar Babu	Retaining wall (Distressed structures)
3.34b	USA	J. A. Sopko	Retaining wall (Distressed frozen earth cofferdam)
3.35b	Romania	C. Capraru	Deep excavations(effects on existing buildings)
3.36b	Turkey	H. T. Durgunoglu	Retaining wall (Flexible earth structures and slope stability)
3.37b	USA	Christopher D. Kiser	Embankment stability (numerical analyses)

Session 3c

Paper	Origin	First Author	Topic
3.02c	Bulgaria	Chavdar Vassilev Kolev,	Conservation of cultural heritage: restoration of masonry construction
3.03c	USA	B. S. Chen	Dewatering: drainage systems and design of shallow foundations
3.04c	Macedonia	Vlatko Sesov	Conservation of cultural heritage: analyses of leaning Clock Tower
3.05c	Bulgaria	M. Todorov	Conservation of cultural heritage: restoration of masonry constructions

SUMMARY OF RESEARCH PAPERS (3a)

Paper No. 3.01a: LANDSLIDE OF TUNNEL FACE BY SLIP CIRCLE FORMATION-CASE STUDY by Kamal Dev Ralh, & Ansh Deep Ralh. The paper describes a landslide occurred in India during the construction of a Railway Tunnel and the countermeasures adopted, after the tunnel face failure, for completing the works. The original project was based on the assumption that the tunnel was passing through an intensely jointed limestone (Sirban dolomite). Indeed the slope failure interested the Reasi thrust (main boundary fault) that mainly consists of crushed dolomite with very high water flow.
Conventional countermeasures were adopted and were divided into three different steps: a) Stabilization and Reconstruction of Portal, b) Re-Entry to Tunnel and Rehabilitation of Damaged Tunnel, c) Stabilization of Hill Slope after Portal Construction and Re-Entry to the Tunnel.
It is not clear if, after the failure occurred in 2005, an alternate alignment of the Railway tunnels under construction was adopted.

Paper No. 3.02a: LANDSLIDE AT RAILWAY PROJECT SITE IN WEAK MURREE FORMATION – CASE STUDY by Kamal Dev Ralh and Ansh Deep Ralh. This paper summarises the factors and constraints on the alignment and construction of the 71km railway line between Katra and Dharam - access to the site was difficult and required the construction of access roads; the geology at the site is soft to hard, shattered and sheared, folded and faulted; the continuous rainfall of 250mm in 60hours, during the construction works, was the worst for many years, and expert advice suggested that the Muree formation is highly prone to landslides even with little rainfall. The authors made very good points about the need for sufficient ground investigation, especially when traversing and cutting into an existing landslide in weak Himalayan geology, as they note that a lot of difficulties were faced when constructing the tunnels due to lack of adequate geological information. It is an interesting paper and in addition to the weak geology the project clearly had other constraints that influenced the railway alignment and design, such as the security of the railway line during operation.

Paper No. 3.03a: CASE HISTORIES OF EARTHEN DAM FAILURES by R. P. Sharma & A. Kumar. The paper presents several earthen dam failure case histories around the world. These dam failures were resulted from some of the more common failure modes such as overtopping, internal erosion and piping. In each case history, the author provided some descriptions of the project site, the reasons that were thought to cause the failure, the results and the consequences of the failure event. The paper illustrated that although these common failure modes were probably known to the designers, failures still occurred when unexpected happened because of different reasons. Lessons learned from the case histories for all concerned should continue looking for ways to improve structural engineering technology as well as non-structural methods such as updating emergency action plan and others to reduce the risk and consequences of dam breaks.

Paper No. 3.04a: SUSCEPTIBILITY ANALYSIS ON LANDSLIDE TRIGGERING FACTORS DURING THE 2008 WENCHUAN EARTHQUAKE by Deping Guo & Masanori Hamada. Guo and Hamada present a very interesting statistical evaluation of over 100 landslides induced by the moment magnitude 7.9 Wenchuan earthquake occurred in 2008 in China. Despite numerous independent and interdependent factors controlling the slope stability, the authors succeeded to develop equations relating sliding area or sliding volume to seismic (peak horizontal ground acceleration), geometric (slope height and slope angle), and geologic (rock type and rock bedding inclination angle) factors. The study is based on remarkable detailed information on both seismic loading and geologic features. The results have direct applicability in practice, by identifying the zones most susceptible to seismic instability and the factors controlling the probable extent of seismically induced landslide area and volume.

Paper No 3.05a: LEVEE FOUNDATION REMEDIATION USING THE DEEP MIX METHOD by Wesley Schmutzler, Filippo Maria Leoni & Kyle Sansing. The paper refers to a project, which its purpose was the improving of the soil beneath the existing levee, in order to increase the height within a limited footprint. The subsoil consists of layers of soft clay, marsh/peat, fat clay and Pleistocene deposits. An overview of the equipment and the methods used in the very large DMM project was given. The binder types, binder ratios and binder factors tested were also briefly described, as well as the acceptance criteria of the DMM. It would be interesting to have additional information on design assumptions and general criteria for the application of different binder ratios and factors to various soil types.

Paper No. 3.07a: SEISMIC RETROFITTING OF SARDIS DAM, USA by Randa Asmar, & Abdul Qudoos Khan. Most of the dams in Central United States built in the earlier part of the 20th century are hydraulic fill dams. At the time of the construction of these dams, earthquake engineering was still in its infancy and therefore the dams lacked proper seismic design. Failure or near failure of dams forced the United States Army Corps of Engineers (USACE) to conduct a comprehensive re-evaluation of the seismic performance of dams in the Central United States. One of these dams was Sardis Dam, which was constructed on a potentially liquefiable weak layer, and which could be damaged by an earthquake of an intensity of 7.5 on the Richter scale. Pre-stressed concrete piles were driven to give additional shear resistance to the weak layer. The paper presents a revision of this rehabilitation work and a prediction of the performance of the rehabilitated dam using finite element method. The foundation soil of the dam consists of a 3 – 6 m thick clay layer, which is underlain by a 12 m thick sand layer. The records of two earlier earthquakes that occurred in California were taken as the design earthquake. In order to ascertain the liquefaction potential of the dam material, the Chinese criteria were used (with some minor modifications). If sufficient data were not available to apply the Chinese criteria, soils with SPT N value < 4 were also assumed to liquefy. The finite element software TARA-3FL was used for calculations. Dynamic triaxial tests were conducted on the dam material and SPT and shear tests were performed to examine the strength of the subsoil. Three potentially liquefiable zones were identified in the foundation soil of the dam, the clay core and the shell on the river side. The study gives an overview of methods earlier applied in the US to prevent liquefaction. Out of the various options, the improvement of the weak soil with pre-stressed, heavily reinforced concrete piles was chosen for the Sardis Dam. Driving 16 – 20 m long piles into the foundation soil with an embedment depth of 4.6 m, a 90 m wide shear plug was formed, the function of which was to transfer the load resulting from the movement of the upstream embankment to the substratum sand. After a revision of calculations, the width of the shear plug was reduced to 50 m. Calculations also verified that the deformations of the dam reinforced this way become minimal.
The study is mostly based on the evaluation of other authors' findings rather than the author's own analysis. However, it is a good example for the presentation of a successful remediation and provides useful lessons.

Paper No 3.08a: EMBANKMENT ON SOIL-CEMENT COLUMNS by Nguyen Minh Hai & Bengt H. Fellenius. The study discusses a slope failure that occurred during the construction of a port on a reclaimed ground in the Mekong delta. The subsoil consists of a thick layer of soft clay deposited on sand. To improve stability and to reduce settlement, the embankment was to be supported by soil cement columns installed on a wide area on the upstream embankment, with vertical wick drains installed at close spacing behind them. A staged surcharge was performed, assuming the positive effect of the consolidation and the hardening of the subsoil. However, the developments did not meet the expectations and the riverbank failed along a long stretch of the embankment in the direction of the river, as investigations confirmed, along a gliding plane. Parallel with the construction, observations were performed using a monitoring system (settlement, pore water pressure, inclinometers). The study gives a detailed description and analysis of the test results. It also suggests that preliminary stability tests were performed (translational sliding and rotational movement on a slip circle), but no details or results are given in this regard. The Conclusions chapter gives a critical summary of the design and construction errors.
To ensure stability, the authors suggest constructing a piled deck platform along the shoreline and widening the enforcement structure by constructing a series of soil-cement columns behind it.

Paper No 3.09a: STABILIZATION OF A FAILED HIGHWAY SLOPE : A MULTI-PHASED APPROACH by Anagnostou Jeffrey T., Flateau Heidi, Nestor Anthony S. & Purushottam (PD) Deo. A county road department in South eastern Michigan was faced with the problem of stabilizing a slope along the Clinton River supporting a heavily trafficked roadway. The slope stabilization objectives included obtaining a minimum factor of safety for global and direct sliding failure mechanisms of 1.3, preferably 1.5 or higher. Slope stabilization was achieved by means of the successful design and construction of an aggregate mattress-columnar reinforcement system for an embankment underlain by normally consolidated, soft to very soft, low plasticity silty clays. The project met various constraints: limited budget of the local country department of roads, environmental sensitivity of the adjacent Clinton River, need to reduce traffic disruptions. The adopted solution was selected among various possibilities and appears to be performing in a satisfactory manner.

Paper No. 3.10a: LESSONS FROM REVISITING THREE CASES OF SLOPE FAILURE by Konstantina Papadopoulou, & George Gazetas. The paper re – analyzes, by means of the F.E. code Plaxis V.8, three old cases of landslides in rock and soil slopes. The numerical analyzes took advantage of field observations, investigation results and capability of the adopted numerical method. The landslides occurred in the following contexts: a) tunnel construction (portal area in a flysch formation), b) extensive failures in a lignite/stiff clay open pit mine and c) slope failure during the Kimola Canal construction (Helsinki).
The causes for unpredicted landslides are: a) unexpected rise of water pressure because of heavy rainfall and inherent difficulties in choosing proper parameters φ′,c′ in soil with intermediate behavior between hard soil and weak rock (non – availability of undisturbed samples and incorrect choice based on rock mass classification system); b) unexpected excessive water pressures after a period of intense rainfalls and in - homogeneity of strength parameters (clay layers/lignite layers) which does not allow the assumption of average values; c) unsuccessful choice of analysis method (undrained conditions)

and selection of strength parameters without taking into account both in homogeneity and anisotropy of the clay.

Paper No. 3.13a: NATURAL FREQUENCY OF EARTH DAMS by Mariam Mahdizardeh & Ali Ghamabari. This is a highly remarkable article: it suggests a simplified "analytical" method for the determination of the natural frequency of dams, which is an important aspect in the examination of the effect of earthquakes on earthen dams.
The value of natural frequency is determined for a sample dam section both by the suggested "analytical" method and by the more scientific "dynamic" method. In an example of a dam of given geometry, with certain assumptions used (dam height: 20 – 100 m, plain strain behavior, linear elastic behavior, constant Poisson's ratio, rigid foundation, zero damping ratio, a given shear wave velocity), the author demonstrates that the results obtained shall be similar and suitable for correlation.
Shear wave velocity and the height of dam determine natural frequency: with the increase of the height of dam, natural frequency reduces and it increases when shear wave velocity or Poisson's ratio increases. Admitting that the "dynamic" method offers a more accurate result, the author demonstrates that under the basic conditions used in the examination the value determined by the dynamic method shall be obtained by dividing the value gained from the analytical method by 1.33.

Paper No. 3.14a: CAUSES AND CIRCUMSTANCES OF RED MUD RESERVOIR DAM FAILURE IN 2010 AT MAL ZRT FACTORY SITE IN AJKA, HUNGARY by David Turi, Jozsef Pusztai & Istvan Nyari. On October 4, 2010 the worst industrial accident occurred in Hungary arousing interest worldwide. The embankment of a red mud reservoir near the town of Ajka broke at one corner and ensuing outflowing alkaline mud has claimed 10 casualties, severe injuries to 286 persons, destruction or damage to 367 properties, and flood on 1017 hectares of mainly agricultural land. Investigations to reveal causes were started immediately after emergency measures, but an attempt to give an explanation for the root cause(s) of the catastrophe was made all the more difficult, since there had been no sign of imminent rupture before the event occurred. The paper provides a comprehensive study of all relevant contributing factors. A review and reassessment of historic data on the design and construction of the dam revealed poor siting of the facility, design errors in calculating safety reserves, as well as lack of proper control in the construction of the dam and its foundation. Laxity in licensing and commissioning, as well as in periodic safety reviews, monitoring and warning system may have their part in leading to this dam failure. External negative factors further converged with the following deficiencies: seismic events in the region, unusual precipitation exceeding an incidence frequency of 3000 years, presence of weak foundation further impaired by cation exchange in the clay, due to high alkalinity of the red mud, counter-effective construction of a diaphragm wall along the outer toe of the embankment, effect of strong wind gusts at the time of failure. A scrutiny of all these factors was carried out and presented in great detail in the paper that was based on extensive post-failure site and laboratory investigations, and 3-D FED stability calculations. The latter may deserve more detailed presentation in future work. The outcome of this study was that failure of the reservoir structure was due to the converging factors of poor siting, design, construction, as well as regulatory deficiencies and unfavorable environmental conditions, none of which can be singled out as the sole agent responsible for failure. One can only consent to the final conclusion of the paper that „The stability of reservoir X was provided by nature and taken away by nature".

Paper No 3.15a: DAMAGE ON A MAIN GAS PIPELINE DUE TO LANDSLIDE OF SOILS DERIVED FROM VOLCANIC ASHES IN COLOMBIA by Gilberto Rodriguez Ch., Julián Rodriguez V. & Natalia Quintero A. The paper refers to a case study of an extensive landslide in Colombia after a period of intense rainfalls. A special reference in damages of a main pipeline, which passes through the failure area, was made. The case history of the slope failure is presented, their causes are mentioned and the division of the wide area in four sectors, as well as the corresponding stratification is explained. The area superficially consists of soil materials derived from volcanic ash (clayey silts and/or sandy silts, covering the weathered bedrock). The peculiar sensitivity of the shear strength of slightly cemented soil materials in variations of the natural water content was ascertained. Conventional stability analyses are described, as well as interaction analysis of the pipeline under 2D conditions. Finally, information about some improvement measurements of stability conditions is given. It could be interesting to consider the dependence of shear strength on slight cementation and partial saturation and the pipeline response to soil displacement.

Paper No. 3.16a DESIGN DETAILS TO ACCOMMODATE FAULT MOVEMENT IN A DAM FOUNDATION by Peter A. Dickson, Joseph R. Kovacich & Georgios Raptis. The effects of fault movements on Dam foundations should be avoided but it is not always possible to precisely identify the fault location and to assess its potential activity. In these circumstances it is necessary to design or re-design the dam in order to minimize the vulnerability of the foundation structure to fault movements. The paper illustrates a very interesting case history in Pakistan, giving the available information about the existing fault (geological and local geotechnical evidences), and the adopted solution (zoned fill section overlying the fault and the remainder of the dam consisting of a concrete gravity feature with integral gated spillway). The effectiveness of the proposed solution has been positively evaluated by means of FE numerical analyses of interaction.

Paper No. 3.18a EARTH DAM FAILURE BY EROSION, A CASE HISTORY by Scott Newhouse. The paper presents a case history of a low hazard earthen dam failure due to progressive erosion and head-cutting through the principal spillway. The failure was a result of a 5-year storm event. It is not clear if the author had been involved in the original design of the dam. The paper does not provide any design details but examines how the failure occurred including the aspects

leading up to the breach. It discusses the obvious violations of basic design, engineering, and operations requirements repeatedly. It is a good case history example that simple but serious violations of these requirements can lead to failure, if miss-calculated or ignored.

Paper No. 3.20a: EMBANKMENT CONSTRUCTION USING COLUMN SUPPORTED EMBANKMENT by Aravinda Ramakrishna, Elizabeth Trimpin & Raymond Mankbadi. The paper deals with soil improvement technique called Column Supported Embankment (CSE). This construction method involves the realization of columns with different technologies and of a platform (Load Transfer Platform) which can be either of geogrid or geotextile. The construction method of such a reinforced soil embankment is not new. Anyway the authors compare the load capacity of different types of column (Controlled Modulus Column, Vibro Concrete Shaft, Vibro Concrete column) and experimentally assess the performance of CSE. The performance of the Column Supported Embankment system is assessed for each system with different installation techniques for the columns and Load Transfer Platforms with either geogrid or geotextile from similar installations in different projects.

Paper No. 3.21a: EVALUATION OF THE FAILURE PROBABILITY OF SLOPES IN RESIDUAL SOIL FROM THE ABURRÁ VALLEY, MEDELLÍN COLOMBIA by Juan Pablo Villada Rodas & Manuel Roberto Villarraga. The paper discusses the use of statistical analysis for evaluation of probability of failure due to slope instability of cut slopes in residual soils in Aburra Valley. The authors analyze the probability of failure using the Taylor series techniques and the First Order Second Moment methodology. Statistical analysis was used to determine the coefficients of variation of the moist unit weight, cohesion, and effective friction angles of gneiss and mud flows. Sensitivity analyses performed to qualify the impact of different factors led to the obvious results that the effective friction angle and the cohesion have a higher impact on the probability of failure than the moist unit weight and that the probability of failure depends highly on the height and the slope of the cut.

Paper No 3.24a: EXPERIMENTAL STUDY OF MITIGATION OF LIQUEFACTION-INDUCED LATERAL DISPLACEMENT USING DEEP SOIL MIXING by Rouzbeh Rasouli, Naoki Takahashi, Ali Derakhshani, Suguru Yamada, Yuji Takaoka & Ikuo Towhata. The paper refers to simulation in shaking table of the improvement method of deep mixing for limitation of ground lateral spreading due to liquefaction. The liquefiable soil layer was submerged loose sand and the columnar deep mixed soil was modeled by cylindrical acrylic columns, which were placed in a central area of laboratory apparatus. The lateral displacements outside and inside the improved area, as well as the excess water pressures were measured and evaluated. The influence of some basic parameters on the above mentioned magnitudes were investigated, such as the area replacement ratio (25%-35%), the pattern of the improvement (regular or irregular) and the length of the improved zone. The experimental measurements were compared with the predictions of the approximate analytical method according to Towata et al (1999). The more important conclusions are focused on the improving influence, mainly of the columnar pattern. The irregular one effectively decreased the lateral displacements and seems to be predominant factor in liquefaction onset delay. It could be very interesting to consider scale effects and testing procedure (geometry, relative density of the sand, frequency of the input ground motion, etc) and the use of the model results in a real scale problem (scale 1:1).

Paper No 3.25a: FAILURES AND REMEDIATION OF ROCK SLOPE STABILITY PROBLEMS AND REMEDIATION AT EARTHQUAKES AT PART OF WERKA DESCENT ROAD WEST OF SAUDI ARABIA by Bahaaeldin Sadagah. The paper deals with various rock failure mechanisms (wedge, plane, toppling and rockfall) and debris flows harming descent roads in Saudi Arabia. Rockfall and debris flows generally initiate from elevations higher than the roads, whilst the other mechanisms concern the road cuts. More specifically, the instabilities interesting the Werka descent road, which is located in mountain area of West of Saudi Arabia, are concerned. The geology of the study area and the Rock Mass Classification (carried out by conventional approaches) are described. The rock mass (metabasalt dry to dump) is of medium to poor quality. Mechanical parameters of rock mass have been inferred from RMR and GSI indexes.
Deterministic analyses of various failure mechanisms have been performed using commercial software (RocScience). Parametric analyses were performed to show the effects of earthquake. A very large range of values for the seismic coefficient has been adopted (Sc = 0.1 – 0.4). The remedial measures are only generically described.

Paper No 3.26a: FINDING F.O.S. FOR FLOW TYPE LANDSLIDE WITH STATIC LIQUEFACTION AT KARSHINGA – A CASE STUDY by Gokul K Bayan The paper addresses the case of a static liquefaction slope failure, a flow-type landslide of colluvial soils for which current analysis methods do not accurately predict performance. The paper presents comprehensive background data on the project area, a history of previous land slide activity in the area, and the site geology. Geotechnical properties of the slide zone are detailed. The role of fluctuating groundwater tables and development of excess pore water pressure in the soils as a result of infiltration of rain water are described. The inability of traditional stability analysis methods to predict recorded performance of landslides in the described conditions are discussed and a new method of estimating factor of safety for the described conditions is presented. The new method starts by following a wedge failure analysis, but adds a "ground softening factor," that helps account for the changes in subsurface conditions as a result of infiltration of rain water. The new method is used to predict factor of safety for varying groundwater depths in the Karshingsa landslide zone.

Paper No 3.27a: FOUNDATION TREATMENT OF EMBANKMENT DAMS WITH COMBINATION OF CONSOLIDATION AND COMPACTION GROUTINGS by Fardin Jafarzadeh Amir & Akbari Garakani. This paper deals with the foundation treatment of the 58 m high Gerbedin dam in North-West of Iran. It is a zoned rockfill dam with a central clay core and due to a 40 m thick weak foundation layer it is susceptible to large settlements. As a remedial measure to reduce the deformations in the dam body, execution of a consolidation grouting zone beneath the clay core was proposed. The stress-strain behavior of the dam body and its foundation has been analyzed by FLAC 2D explicit finite difference program. Principles of the program and the modeling assumptions are broadly outlined. Also a sensitivity analysis has been performed between two extreme conditions:
(1) the elastic modulus of the grouted zone be equal to that of the weak alluvial foundation (no grouting);
(2) the elastic modulus of the grouted zone be 1100 times that of the alluvial foundation (fully concreted grouting zone).
A detailed study of vertical and horizontal deformations is presented and excellently illustrated for both no-grouting condition and fully grouted condition. Results of modeling and sensitivity analysis show that the reinforcing grouting has a significant role in reducing vertical deformations in the dam body after construction. Moreover, the optimum stiffness ratio [E(grouted zone)/E(alluvial foundation)] is about 100. Eventually, field test of grouting procedures have been used to find the most appropriate grouting geometry (drilling grouted columns 2 m center to center) in order to obtain the desired value of the grouted zone stiffness. The paper is a fine example of selecting and analyzing numerically an effective remedial solution.

Paper No. 3.28a: THE INFLUENCE OF FREEZE-THAW CYCLES ON CBR VALUES OF SILTY SOILS STABILIZED WITH LIME AND MICROSILICA by Reza Ziaie Moayed, Younes Daghigh &Behzad Pourhadi Lahiji. The paper illustrates an experimental study carried out to evaluate the capability of a stabilized silts to well perform as subgrade material for the Karaj railway (Iran). The considered soil is a sandy – clayey silt and has been stabilized by adding lime and microsilica in different percentages. Microsilica (or silica fume) is one of the by- product materials which is obtained from silicon material or silicon alloy metal factories. The experimental tests have been carried out on specimens prepared at the optimum water content in order to evaluate the CBR variation with additive percentages. The optimum percentages have been identified as 5 % lime and 12 % microsilica (not very clear the economic aspect). The effect of freeze –thaw cycles have also been tested. The main result is that a single freeze – thaw cycle cause a reduction of 90% of the CBR. Additional cycles have negligible effects.

Paper No 3.29a: BACKWARD EROSION PIPING MODEL VERIFICATION USING CASES IN CHINA AND THE NETHERLANDS by V.M. van Beek, Q.L. Yao & M.A. Van Three well documented cases of piping developed in the sandy foundation of dikes in China and the Netherlands were presented and evaluated. Cross sections of the levees, simplified geotechnical logs, information of the grain size distribution of the sandy layer and the water level variations are given. The critical hydraulic heads were calculated for each case by the help of two well-known prediction models and were compared with the actual head drop across the levees. It was concluded that the Bligh's simplest model is easier to apply than the Sellmeijer's one which is sensitive to the input parameters and may result to serious uncertainties.
It could be interesting to find out the grain size distribution parameter more relevant for piping or foundation scour phenomena and the practical applicability of the considered models with many input parameters.

Paper No 3.30a: GEOTECHNICAL CHARACTERIZATION OF THE FLOOD PLAIN EMBANKMENTS OF THE SERCHIO RIVER (TUSCANY, ITALY) by Barbara Cosanti, Nunziante Squeglia, & Diego C. F. Lo Presti The paper describes an extensive geotechnical investigation of multiple levee failures along the Serchio River in Tuscany, Italy. Electrical Resistivity Tomography (ERT) and CPTU data, specifically Robertson's 1990 Soil Behavior Type (SBT) estimations, are compared with traditional boring and testing methods. These results show a low success rate at matching both ERT and CPTU values with traditional soil classification descriptions, reinforcing the need for proper calibration of such data. Soil permeability and shear strength are also evaluated to develop parameters for the geotechnical model used to analyze the failures, which is covered in a companion paper. The influence of soil water content on ERT is addressed, including the effects on estimation of soil type. Sampling of very loose materials with different tools and the impact on measured soil parameters is discussed.

Paper No 3.31a: HIGH-RISK FLOOD CONTROL DAMS ON DIFFICULT SOIL FOUNDATIONS by Gary S. Chow, P.E., Lori K. Thomas & Willis Walker. The paper provides a summary of historical repairs and existing conditions at the Addicks and Barker Reservoirs dams located near Houston, Texas. The presence of erodible fine sand and silt foundation soil conditions has led to several damages in the past. Historical attempts to both repair the damages and prevent further erosion and undermining of the structures are described. This paper takes a wide-view of the historical repairs, and begins to analyze the potential failure modes that are currently presenting risk to the dams. Interim Risk Reduction Measures that are currently being implemented are discussed, along with alternatives for long-term solutions to the problem soils.

Paper No. 3.32a: INVESTIGATION OF THE EFFECT OF MODELING OF CONTROL TUNNEL IN RETAINING STRUCTURE OF J2 STATION OF MASHHAD METRO USING PLAXIS 2D by S.M Mousavi, F.Rouzmehr & A.H.Fazli. The paper deals with numerical analyses of retaining structures for underground construction (Metro station). The Authors stress the importance of performing the numerical analyses by considering the presence of the "control

tunnel". The results of analyses with and without control tunnel are not so dramatic. On the other hand, the paper does not give too many details on the analyses. In particular it is not clear how different stages of construction have been considered using the code Plaxis 2D.

Paper No. 3.33a: STABILITY ANALYSIS OF BEHESHT ABAD WATER CONVEYANCE TUNNEL INLET PORTAL USING EXPERIMENTAL, LIMIT EQUILIBRIUM AND NUMERICAL METHODS by Arash Mohammadi, Mahmoud Hashemi and Hooman Sharifpour. The paper illustrates the stability analysis of the rock mass surrounding the Behesht-abad Water Conveyance Tunnel portal faces. This Tunnel is one of the most important tunnels conveying water to central Iran with length of 60 km and 6 m diameter. The Stability analyses were conducted using stereographic, empirical SMR, limit state equilibrium and 3-dimensional discontinuum numerical methods. The author is trying to show how the results from the different methods can be compared

Paper No. 3.34a LANDSLIDE STABILIZATION ALONG THE OHIO RIVER USING CANTILEVERED STUB PIERS by Swaminathan Srinivasan, & Jess A. Schroeder. The paper deals with the problem of stabilizing a landslide characterized by a deep shear plane. The landslide under study occurred in 2005 along U.S. 50 in Cincinnati, Ohio. The slope movements sheared the casing of installed inclinometers (just a few week before) at a depth of 50 ft near the soil bedrock interface. As a consequence of these movements 3 lanes were closed and emergency stabilization measures were undertaken to protect the roadway by providing a "pseudo" short-term solution (target 3 to 5 years) necessitated by ODOT budget constraints. "Stub Piers" were installed 40 feet downslope of the roadway shoulder. The shafts were heavily reinforced across the deep shear plane but steel reinforcing did not extend the full length of the shafts and was stopped well short of the ground surface. These "Stub Piers" were installed in three months in the summer of 2005 and found to meet all of the project goals (short time for installation, much lower cost in comparison to other solutions and very limited movements). The stub piers and surrounding ground were instrumented (2005 – 2012) and analyses of collected data to date showed earth pressures and horizontal deflections were over-predicted in the original design. The described solution offers an attractive alternative to conventional drilled piers or tiedback drilled pier solutions.

Paper No. 3.36a: KOMAN CONCRETE FACE ROCKFILL DAM UPDATING THE STATIC AND SEISMIC EVALUATIONS by Hamid Fallah & Martin Wieland. In this paper the static and seismic safety evaluation of the 115 m high Koman concrete face rockfill dam has been checked according to the current state-of-practice for the seismic safety evaluation of large embankment dams. The static analysis was carried out by a Mohr-Coulomb elasto-plastic material model of the rockfill. The safety of the dam was checked for the safety evaluation earthquake (SEE). Spectrum-compatible artificially generated accelerograms were used. The peak absolute horizontal crest acceleration due to the SEE excitation is about 0.78 g for average material properties, and about 1.16 g for the most unfavorable material properties. The maximum crest settlement resulting from the sliding displacements plus an additional settlement due to the vibration-induced densification of the dam body are calculated as 0.98 m, under the most unfavorable conditions. Two-dimensional dam model is only adequate for the assessment of the deformations of the dam body but not for the safety of the concrete face. For the latter a three-dimensional model of the dam is required as the stresses in the concrete face depend on (i) the deformational behavior of the dam during the SEE, (ii) the detailing of the vertical joints, and (iii) the cross-canyon component of the SEE.

Paper No. 3.38a: M-222 SLOPE STABILIZATION CASE HISTORY – GEOTECHNICAL LESSONS LEARNED FROM MICHIGAN DEPARTMENT OF TRANSPORTATION DESIGN BUILD PROJECT by Michael J. Thelen, & Daniel A. Thome. The paper illustrates the slope movements, due to river erosion (Kalamazoo River – City of Allegan, Michigan). Since 2009, Kalamazoo River scouring caused slope movements adjacent to a segment of M-222. Countermeasures for slope stabilization were designed since spring of 2011 and included constructing an up to 26-foot tall retaining wall, re-grading the roughly 70-foot high slope, and armoring the toe of slope. Construction of the project began in July of 2011 and was completed in spring of 2012. The paper gives a history of the slope instability progression using aerial photography. The design of the retaining wall has been done considering Ultimate Limit States and durability of the structure according to available guidelines that are critically discussed in the light of the case history evidences.

Paper No. 3.39a MISSISIPI RIVER ROAD GABION WALL/SLOPE STABILIZATION by W. Ken Beck & Lok M. Sharma. The paper deals with the geotechnical investigations, back – analyses and design of stabilization works of a slope along the Missisipi River Road. The slope was supported by gabions before the .slope instability became evident. The landslide was triggered by significant precipitation in the spring of 2010 and mainly consisted of debris translation above the underlying shale. After geotechnical characterization of the soil interested by the instability phenomena and reconstruction of landslide geometry (inclinometer monitoring was also used), the designed solution (not yet realized) consisted of tied back closely spaced drilled shaft.

Paper No. 3.40a OBSERVATIONS SAVE THE DAY AT THE WACHOVIA CULTURAL CENTRE EXCAVATION by D.Bruce Nothdurft, E.J. Cording & J.Sid Davis. This is a very interesting paper that discusses and promotes the use of the observational method, which was invaluable in this project. The construction required an excavation of nearly 100ft deep into rock but at a depth of 40ft cracks started to appear in adjacent buildings. The observational method,

combined with inclinometer readings, identified a clay-filled seam dipping into the excavation. The sliding block was stabilized and no further movement was observed. This case study illustrates the importance of site supervision by proficient geotechnical engineers, without whom the minor damage to surrounding structures and the works themselves is likely to have been much more serious, leading to huge cost to the project and serious risks to the safety of site staff and third parties.

Paper No. 3.41a: RECONSTRUCTION OF ROAD EMBANKMENT FAILURE USING REINFORCED GEOGRID: REVISITING THE SITE AFTER 15 YEARS by Suhaimi Jamaludin & Kamal Bahrin Jaafar. The paper illustrates a case history of repair works of road embankment failure at km 39 Route 68, Kuala Lumpur – Bentong Road in the state of Selangor, Malaysia and an observation on the condition of the site after 15 years and some tensile strength testing carried out on buried and exposed geogrid. The case history includes soil characterization, stability analyses and the adopted repair technology. More interestingly the paper gives information on the repaired embankment after 15 year life and on the strength of geogrid by means of laboratory tensile testing. Two groups of sample were taken: buried geogrid and exposed geogrid. Buried geogrid will present the geogrid with protection from harsh weather such as ultraviolet effect and other external factors, whereas exposed geogrid will present the geogrid with no protection. The size of each sample is 600mm (Wrap) by 200mm (Weft). The Wide Width Tensile Test was carried out using split roller grips on the single strand of geogrid. This test procedure is based on ISO 10319-2008. Results of the laboratory tensile testing shows there are no significant reduction of strength observed after 15 years.

Paper No. 3.42a: REMEDIATION OF A SLOPE FAILURE ABOVE RETAINING WALL UNDER CONSTRUCTION by Miroslav Cerny & Lubos Hrustinec. The paper deals with a slope failure originated above a retaining wall under construction for the D1 Highway in Slovakia. The landslide was reactivated after snow melting in winter 2010. Cut slope above the built retaining wall has failed approximately on area 4500 square m with a few breaches, where the maximum height of segregation was about 2.5 m. Supporting pier of high voltage has failed during the landslide. Before the landslide remediation works has started some inclinometers were built which helped to determine assumed sliding surface and observe the further development of the landslide during its remediation. Final recovery works consisted of the reduction of slope angle and drainage slope by sub − horizontal drill holes and drainage ribs.

Paper No. 3.44a: ANALYIS AND DESIGN OF BREAK-WATER FOR SEA WATER INTAKE FACILITIY ON SOUTH EAST COAST OF INDIA by Jaykumar Shukla, Laxman Rajwani, & Dhananjay Shah. The paper deals with the design and analysis of a breakwater for a sea water intake facility. Because of the poor foundation conditions at the project site, different design and construction alternatives have to be examined and analyzed carefully in order to provide a cost effective and engineering feasible structure to serve the propose of the project. The paper provides discussions of geotechnical investigation efforts and analyses of geotechnical data to assess ground improvement methods for settlement and slope stability issues. The paper recommends stage construction using Prefabricated Vertical Drains (PVDs) ground improvement method as a feasible alternative. It is not clear if the project was actually completed with the recommendations nor there are any monitoring data to validate the effectiveness of the design recommendations.

Paper No. 3.47a TECHNICAL ANALYSES AND LESSONS OF THE EMBANKMENT FAILURE AT THE AJKA RED MUD RESERVOIR by József Mecsi. The paper deals with a dam failure of a production waste disposal reservoir in Hungary. Red mud is a waste product from several alumina plants that was contained in the reservoir. The paper provides a detail background of the project site and an informative fact-based description of the reasons thought in resulting in the dam failure. Considerable investigation information data are provided and engineering analyses attempted to explain the reasons for failure are described. However, the paper did not really confirm or come to a final conclusion of the primary failure mode that caused the failure of the dam.

Paper No. 3.48a: CASE STUDY OF LANDSLIDES IN KABYLIA REGION, ALGERIA by Sadaoui Omar, Sadaoui Sami & Bahar Ramdane. The paper illustrates a well-documented case history of landslide of large sizes in Algeria and its effect on existing infrastructures. The paper gives detailed information on the geology of the study area. The existence of debris deposits overlying non permeable marly limestone bedrock. Heavy rainfall is the main triggering factor together with the absence of drainage. The landslide under consideration caused the collapse of a 120 m long section of the road, with a main scarp of about 8 meters. During the firstly time of the field observation, 18 hours, the landslide mass and the road moved 10 meters. The effectiveness of the designed countermeasures has been assessed by means of numerical analyses (Limit equilibrium and FE) supported by appropriate geotechnical characterization. The analyses also clarified the failure mechanism.

Paper No 3.49a: FIELD TESTING OF CRUSHED IGNIMBRITE FOR SEISMIC RETROFIT OF MATAHINA DAM by Lelio H. Mejia. The paper presents the results of field and laboratory testing of a crushed ignimbrite rock to evaluate its suitability as filter and drain material for the seismic retrofit of Matahina Dam (New Zealand) to withstand foundation fault rupture. The program included construction of two test embankments. Field testing of the embankments included density, pipe pullout and trench collapse tests. The latter two types of tests were performed upon completion of the embankments to assess the propensity of the materials to support open cracks and cavities in the field. Laboratory testing included gradation tests on the samples retained from

the field density pits, and 'sand castle' tests (ICOLD, 1994) on samples of the filter embankment materials.
The paper also discusses key issues associated with the design of filters to mitigate the risk of dam cracking

Paper No. 3.50a: GEOTECHNICAL ASPECTS FOR PROTECTION BUNDS by Janvi Talsaniya, Vaishali Pandya & Jigar Rana The paper presents the use of "rubble mound protection bund" and earthen embankment to protect a pump station water storage pond for a sea water intake structure in the Gulf of Khambhat in India. The paper provides detailed information on the geotechnical analyses performed for the design of the earthen embankments including bearing capacity, settlement analyses, seepage analyses through the earthen embankment, slope stability analyses considering the hydrodynamic wave action, or for static and seismic condition, and determination of the liquefaction potential of the foundation soils. Hydrodynamic wave analysis was used to design the stone protection for wave breaker and erosion control. The paper is interesting; it shows the use of non-conventional materials such as rubble for construction of dikes protecting a water storage pond from sea waves. It may be interesting to develop more the procedure used for wave modeling studies eventually.

Paper No. 3.51a: HIGHWAY SECTION AFFECTED BY TWO NEIGHBORING LANDSLIDES – PERFORMANCE, MONITORING AND DESIGN OF STABILIZATION MEASURES by Vassilis Houssiadas, Eleni Sakoumpenta & Manolis Haralambakis. The paper gives the geological context (highly tectonized gneiss, schist and marble), geotechnical characterization and monitoring results of two deep seated creeping landslides affecting the Egnatia Odos 670 km-long highway crossing Northern Greece. More specifically, 65 m high embankment and a 240 m long tunnel are affected by these two huge landslides. The monitoring data concern at least the last 5 to 8 years. The paper is a very interesting case history about creeping landslides.
As for the countermeasures, the design of a 700.000 cubic meters toe berm is illustrated with the results of stability analyses.

Paper No 3.52a: EFFECT OF THE SOIL SPATIAL VARIABILITY ON THE STATIC AND DYNAMIC STABILITY ANALYSIS OF A LEBANESE SLOPE by Mansour Neaimeh, Rony Azar, Roni Hmaymes, Georges Nasr, Dalia Youssef Abdel Massih, Jacques Harb, Nancy Salloum, Cécile Cornou & Denis Jongmans. By the reason of the static and dynamic analysis of a Lebanese slope (stable today, of which the stability remains critical) several issues, such as shear strength variability of the soil and the methodology of approach, are presented. The area under investigation is about 10000m^2, is mainly covered by clayey sand and with local layers of gravel and/or expansive clay. The in situ investigation included conventional in situ and lab tests, as well as Soil Electrical Resistivity Tests. Moreover, the methodology of statistic elaboration of data and the stability analyses is described in phases. Firstly, a static deterministic analysis under 3D conditions was carried out. In critical sections which were pointed out, probabilistic analyses under 2D conditions followed. Dynamic analyses in critical sections had as purpose the estimation of amplifications at the top of the slope due to site effects, as well as the estimation of an envelope of the response spectra. Finally, the advantages of the probabilistic approach versus the deterministic one were indicated. Although the slope under consideration seems stable today, it has already moved in the past. It is not completely clear which factors are more influent: shear strength reduction, the existence of a potential slip surface, or the strength variability as observed in the laboratory testing.

Paper No 3.56a: OVER EIGHT DECADES OLD "YOUNG" LANDSLIDE- A CASE STUDY by Kishor Kumar , P. S. Prasad, Anil Kathait & Indervir Singh A case study of an extended landslide in North India is presented. The first activation occurred before 90 years approximately and the landslide reactivated in different time periods. The area is covered by metavolcanic rocks and quartzites, shales and covering thin layers of debris. The slope failures have a complex type, combination of slide, rockfalls and flow. Detailed descriptions are given, concerning the geological, geomorphological and geotechnical investigations at the site under consideration, as well as information of a simple monitoring system and the measurements. The development of the failures and the surface displacements depended on the rockmass classification data, according to the systems RMR and SMR, as well as the time appearance of intense rainfalls. The investigations and analyses helped to approach the causes and mechanisms of the slope failures and to design the remedial measures. Discussion on shear strength dependence on long-term large displacements and the rate of deformations should be useful.

Paper No. 3.57a: RAINFALL-INDUCED DEBRIS FLOWS CASE HISTORY ALONG AL-HADA DESCENT HIGHWAY WEST OF SAUDI ARABIA by Bahaaeldin Sadagah, Abdulrahman Al-Amri , Mohammed S. Aazam & Omar Al-Hoseiny. The paper describes the damages caused by large debris displaced by run-off after heavy rainfall on a very sharp 2000m long descent road. The road intersects steep gullies of 60 to 80 degrees containing mud, old levees and large rock blocks. The debris are caused by erosion of the channel bed, which lead to landslides and to destruction of the natural dam causing extensive damages on the road and its elements such as retaining walls and gabions. The paper analyzes the mechanism of debris flow movement and proposes temporary as well as permanent solution to reduce and stabilize the debris flow. The paper is interesting, however, the proposed solutions are not studied in detail and technically justified.

Paper No.3.60a: SETTLEMENT PREDICTION OF LANDFILL IN IRAN by S .A. Naeini & M. A. Jahanfar. The paper studies the possible damages of compacted clay liners in Waste Disposal that can be induced by differential settlements. The paper analyses the behavior of the Houshang Abad

landfill by means of finite element analysis. Reference geotechnical characterization of soil and waste is assumed from published papers. The numerical analyses are carried out in a parametric way to point out the most influential factors. Numerical results show that settlement is significantly dependent on the waste geotechnical parameters. Tensile strains appear in the CCL, the maximum amount of tensile strains occur at the L/3 (L is the width of landfill) from the center of landfill due to a saturation effects in the waste body as a result of inefficient drainage system. The study does not consider the effects of settlements on the serviceability limit state of the liners.

Paper No. 3.61a: SELF HARDENING SLURRY WALL INSTALLATION BY HYDROMILL AT THE HERBERT HOOVER DIKE – AN INNOVATIVE SOLUTION by Mario Mauro, Carlos Morales & Jeff Taylor. The paper discusses the application of the hydromill technology with self-hardening slurry for construction of a seepage cut-off wall for improvement of a dam in USA considered as a high risk due to seepage through its foundation and through the embankment. The seepage cut-off wall was constructed in an approximately 80 feet deep trench excavated through the embankment and foundation below a limestone layer. The self-hardening slurry consisting of a mixture of water, bentonite, cementation binder and additive was used for both as supporting fluid as well as final backfill material, reducing the time of construction and the cost of the cut-off wall. The trench was excavated with mechanical and hydraulic clamshells through the embankment and the foundation soil and with hydromill equipment in the limestone rock and sand. The paper describes also some of the methods used to determine the continuity and homogeneity of the wall as well as the strength and permeability. The paper essentially deals with the technological aspects.

Paper No 3.62a: STABILITY ANALYSIS OF THE SERCHIO RIVER FLOOD PLAIN EMBANKMENTS (TUSCANY, ITALY) by Nunziante Squeglia, Barbara Cosanti, & Diego C. F. Lo Presti The paper describes different possible causes of the failures for multiple levee failures along the Serchio River in Tuscany, Italy. Piping, heave, and slope instability are evaluated. The results are compared from analyzing several different sections using three limit equilibrium analysis commercial software tools: Slide, PC-Stabl, and Slope/W. The stability analyses also showed that many of the analyzed sections had very low factors of safety, some below unity, which led to further investigation using the FEM analysis (PLAXIS) and consideration of partial saturation of the soils and non-steady state seepage conditions. Using the analyses of the failed sections and the results from an extensive geotechnical investigation, described in a companion paper, the remaining levee reach is screened to identify areas considered at risk of future failures.

Paper No. 3.63a: STABILIZING A LANDSLIDE ON A HIGHWAY UNDER TRAFFIC: A CASE HISTORY ON EGNATIA MOTORWAY IN GREECE by Eleni Sakoumpenta , Vassilis Houssiadas & Manolis Haralambakis. The paper describes a landslide occurred on winter 2010 affecting an embankment approximately 300m long and 8–20 m high of the Egnatia highway in Northern Greece. The crest of the slide was at a distance of 60m uphill from the highway and the maximum depth of movement was 28 m. A horizontal movement of 30cm was recorded with an initial rate of up to 15mm/day measured by the numerous inclinometers that were installed. Immediate measures were adopted consisting of dewatering through pumping wells constructed in the central reserve between the two carriageways and unloading through earth removal from the crest of the sliding mass. These measures resulted in a significant mitigation of the movement allowing for the design and construction of permanent stabilizing measures (mainly shear keys) whilst the motorway remained under continuous operation. A staged approach was applied in the design and construction of the remedial works based on the constant monitoring of the slide behavior through inclinometers. The paper also shows the geotechnical model and the geometry of the sliding based on the results of the geotechnical investigation and the extensive network of instruments that were installed. It discusses the alternatives examined and the stabilization measures that were designed and eventually implemented. Finally, it outlines the construction sequence and assesses the effectiveness of the stabilization measures to date based on the geotechnical instrument monitoring. Monitoring of the staged stabilization is the most interesting aspect of the paper

Paper No. 3.65a: SEISMIC RETROFIT OF CRANE VALLEY DAM by David Ritzman, Faiz Makdisi, Joseph de Larios, Joseph Sun & Charles Ahlgren. The results of seismic stability analyses performed in 2005 and 2006 showed that Crane Valley Dam would experience large deformations as a result of the postulated ground motions during design-level earthquake events. To improve the seismic stability and performance of the dam, PG&E initiated the Crane Valley Dam Seismic Retrofit Project, which includes raising the dam crest, placing new rockfill buttresses on the upstream and downstream slopes of the dam, constructing internal drainage improvements, and reinforcing portions of the concrete core wall. Project components were designed to meet seepage control and seismic stability criteria and to accommodate existing facilities, limited site access, seasonal reservoir operations, and environmentally sensitive areas within and adjacent to the Project site. Engineering analyses included static, seepage, and dynamic finite element analyses to evaluate the potential for liquefaction of hydraulic fill materials and post-earthquake stability of the retrofitted dam embankment.

Paper No. 3.66a: SELECTION OF MOST APPROPRIATE PROCEDURES FOR SEISMIC EVALUATION OF LEVEES BASED ON CASE HISTORIES by Vlad Perlea, Khaled Chowdhury, Mary Perlea, & George Hu. The paper describes in detail the seismic evaluation of the Pajaro River levee near Watsonville, California, which was severely damaged by seismic liquefaction of the alluvial deposit below the levee

during the 1989 Loma Prieta earthquake. Based on the results of the analyses presented by the authors, which included liquefaction assessment, post-earthquake limit equilibrium evaluation and lateral spreading evaluation, several observations are made that are relevant in the analysis of levees.

Paper No. 3.67a: THREE DIMENSIONAL SOIL-STRUCTURE - INTERACTION ANALYSIS OF A FLOOD WALL UNDER FULL-SCALE LOAD by Jian Hu, Faiz Makdisi, Zhi-Liang Wang, Kent Hokens, & Neil Schwanz. The paper reports the results of a series of full-scale load tests performed on a continuous steel, I-shaped, sheet pile flood wall that was subjected to hydrostatic loads and simulated actual flood conditions. The load tests were performed in Tell City, Indiana by the United States Army Corps of Engineer. In order to investigate 3D effects, 2D and 3D FLAC analyses were done by the authors. Predicted and measured wall displacements were compared. Wall deflections predicted with the 3D analysis were ¼ to ½ of those predicted with the 2D analysis. The predicted wall deflections increased substantially when gap formation behind the wall was considered.

Paper No. 3.68a: GROUND MOTION AMPLIFICATION FROM VERTICAL PROPAGATION OF EARTHQUAKE WAVES by Nien-Yin Chang & Roger L Torres. In this paper, a 1-D shear-wave propagation program was used to investigate how a soil deposit with nearly horizontal layers having different shear wave velocities can attenuate or amplify the ground motion when the shear wave propagates upwards through it. In addition, an embankment dam located on the west coast of the United States was also analyzed with small-strain shear modulus estimated from field shear-wave velocities measured using cross-hole and down-hole geophysical tests. A nonlinear relationship is used to express the variation of the shear modulus with shear strain. The authors suggest that the results obtained from the one-dimensional wave analysis can be used to assess whether more realistic 2D or 3D site response analyses are necessary.

Paper No. 3.70a: LATERAL MOVEMENTS OF A BRIDGE ABUTMENT DUE TO COMPRESSIBLE FOUNDATION SOILS by Alper Turan, Tony Sangiuliano, M. Shahria Alam & M. Hesham El Naggar. The paper presents a case history on the interaction between approach embankment on soft soil and bridge abutments on piles. More specifically, the abutments of seven bridges on the Macdonald-Cartier Freeway between Carnwall and the Quebec border experienced excessive movements, which resulted in extensive repair work in three of these structures. It is supposed that movements of the bridge abutments are mainly caused by excessive settlements of the approach embankment. The paper gives the geotechnical characterization of the foundation soil, the results of monitoring of embankment - settlement, the movements experienced by the abutments and the results obtained using 2D nonlinear finite element analyses carried out by means of the commercial software package, PLAXIS 2D. The FEM analyses were carried out to evaluate the forces and moments acting on the abutments as a result of embankment loading. The behaviour of compressible soils is modelled using Soft Soil Model (SSM). The results indicated that the consolidation settlements and their impact on the abutment piles were estimated with an acceptable accuracy using FE model. The results presented in this study are considered to be of interest to researchers and practitioners.

Paper No. 3.75a: LARGE SETTLEMENT OF CLAY CORE IN ROCK FILL DAM, TURKEY by Atla Sezen & M. Atilla Ansal. The study engages in the analysis of the unexpected settlement and consolidation behavior of the clay core in the 184 m high Atatürk rock fill dam. The properties of the clay core are as follows: Ip=32%, $\rho dmax$= 14,9 kN/m^3 (which is an unusually low value); the material of both the protected side and the river side of the dam is basalt of various types. It is unfortunate that the article does not present a typical cross section. A significant difference was experienced between the measured settlement data of the dam (1.6 m) and the data calculated based on laboratory tests, but by changing the parameters based on a back analysis, a much better fit was obtained with the conditions prior to the reservoir filling (the value of the consolidation index (Cv) was increased by 200 times). However, significantly large settlements were observed within the clay core located approximately 120 m below the crest following the reservoir filling. Nevertheless, the measured and the calculated settlements did not overlap even with repeated assuming unlikely consolidation parameters. Earlier analyses quoted in the study describe cases (e.g. the El Infiernillo Dam and others) where extremely large settlements occurred due to the stress caused by large dimensions, as a result of partly the relative displacements between the different zones of the dam and the ensuing rearrangement of stress, and partly the unfavorable alternation (the reduced strength) of the substance of the clay core and the rock filling. According to the study it is these factors that contributed to the extreme settlements in the case of the Atatürk Dam, too: the settlements accelerated following the filling of the reservoir and within a few months they reached a level where they could not be modeled with any known approach or analysis. According to the study, this fact also supports the hypothesis that the water – as also confirmed by petrographic analyses – induced an unfavorable change in structure (swelling, weathering, loss of strength) and instability in the material of the basalt rock-fill zone; this, as well as the lateral spreading of the clay core into the filter material and the shell zone could have caused the extreme settlements.

Paper No. 3.76a: INFLUENCE OF DAM AND FOUNDATION DISCOUNTINUITIES USING DISCOUNTINUUM APPROACH - A CASE STUDY by Shilpa Pal and Dilip K Paul. In this paper Influence of discontinuities on stability of concrete dams was investigated. The Authors study two case histories; one of them (Koyna dam) was analyzes using 2D modeling the second was analyzed using 3D modeling. From the 2D-DEM modeling of the post crack behavior of the cracked Koyna dam it was

found that interface properties (Shear Stiffness Ks, and damping at crack surface) are sensitive to the behavior of cracked dam. A parametric study of the crack profile at the neck of the Koyna was also performed. The 3D study concludes that the effect of dam discontinuities on the response during the seismic load clearly indicates that the dam analysis with no discontinuity in the dam or monolithic structure does not provide a realistic response as the dam monoliths periodically open and close with the excitation of the external seismic force. Analysis of dam with rock interaction i.e. inclusion of rock discontinuities or condition prevailing in the field should be considered for the analysis which represent actual events taking place in the field. It is observed that after including foundation discontinuities relative transverse displacement and permanent displacement between dam monoliths increase by 25% and 80% respectively. It is observed that most of the permanent displacement in the dam occurs at the end of earthquake motion due to the plastic movement at the dam and foundation discontinuities. It is clearly indicated from the study that the interaction between dam monoliths and discontinuities in the foundation rock mass should be a necessary part of the gravity dam analysis.

SUMMARY OF RESEARCH PAPERS (3b)

Paper No. 3.01b: CASE HISTORIES OF FAILURE OF DEEP EXCAVATION EXAMINATION OF WHERE THINGS WENT WRONG: NICOLL HIGHWAY COLLAPSE, SINGAPORE by John Endicott. An extremely interesting paper that accounts the events leading up to the failure, the identification of the causative factors, and the reasons for the total collapse of the Nicoll Highway. The author's conclusions are a stark reminder that analyses using computer programs should not be delegated to inexperienced staff due to their lack of appreciation of fundamental concepts. The author also raises a concern that although a number of procedures have been introduced and implemented by the Building and Construction Authority they are still either unknown or are not being followed, resulting in similar mistakes being repeated.

Paper 3.02b UNDERPINNING A RESIDENTIAL STRUCTURE ON UNCONTROLLED FILL WITH HELICAL SCREW-PILES by Alan J. Lutenegger: The paper illustrates the time evolution of damages occurred to a two story wood frame single-family residence constructed in 1996. Underpinning of a private residence using square-shaft helical Screw-Piles is described. in a small subdivision started to experience differential settlement not long after construction. The geotechnical investigations carried out to identify the causes of such a damages are also described. Investigations pointed out that the area of the housing development had previously been used as a commercial sand and gravel pit which had subsequently been used as a local dumping area for miscellaneous refuse and which had then been covered by a layer of sand and gravel. In order to stop additional movement, a series of square-shaft helical Screw-Piles was installed around the perimeter of the structure extending through the fill to the underlying dense sand and gravel. Foundation brackets were attached to the existing concrete footings for transferring load to the Screw-Piles. A description of the underpinning work is presented to illustrate successful use of Screw-Piles for underpinning lightly loaded structures.

Paper No. 3.03b: NUMERICAL INVESTIGATION OF THE MOBILIZATION OF ACTIVE PRESSURE ON RETAINING WALLS by Abouzar Sadrekarimi & Sepideh Damavandinejad Monfared. The paper presents a parametric numerical study into the mobilization of active pressure behind traditional gravity walls. The results of numerical analyses (calculations were performed with ABAQUS and the extended Drucker-Prager plasticity model), were compared with pressure distributions obtained from simple limiting equilibrium theories (such as Coulomb's and Rankine's) and with results of physical-model experiments by Terzaghi (1934) and Sherif (1984). The authors also investigated the effect of wall displacement, wall-backfill and subsoil-wall-backfill interaction on the mobilization of the active condition. Among the main findings, the authors found that the active state behind the retaining structure is mobilized for wall-displacements smaller than those measured by Terzaghi in his physical model tests.

Paper No. 3.04b: NUMERICAL ANALYSIS OF SOIL DEFORMATIONS AROUND DEEP EXCAVATIONS by Oktay Sevencan, Kutay Ozaydin & Havvanur Kilic. The paper presents a useful comparison between measured and 2D FE computed horizontal displacements induced by the excavation of the Cincin deep metro station in Istanbul. The excavation (32.5m deep) was conducted in clays and clayey sands with diaphragm walls and top-down technique (the station slabs and the foundation mat were used as support elements). The numerical analyses were conducted with PLAXIS in drained conditions. The comparison between measured and computed wall displacements was used by the authors to validate the numerical model and, after this step, to make further considerations on the opportunity to support the excavation with alternative methods such as secant pile walls with pre-stressed tie-backs or internal steel pipe bracing. The authors concluded that if the excavation would have been supported by drilled piles and multi-level tiebacks, larger soil movements around the station could be expected.

Paper No. 3.05b: BEHAVIOR PREDICTION AND MONITORING OF A DEEP EXCAVATION IN THE HISTORIC CENTER OF BRESCIA by Alex Sanzeni, Francesco Colleselli, Moira Mino & Alberto Merlini. The paper presents the construction of a new underground car park in the historic center of Brescia (Northern Italy). Such a construction requires a 15-20m deep excavation between two facing ancient walls (15-16th century) that support 3-4 story buildings in precarious conditions. The vertical cut was supported by concrete multi-anchored diaphragm walls. A comprehensive monitoring system was set up before

construction and a number of finite element numerical analyses were conducted using different constitutive laws for the soil to evaluate the behavior of the retaining structure and safety of adjacent buildings. The result of numerical analyses performed with soil models that include isotropic hardening with stress and strain stiffness dependency compared well with measurements.

Paper 3.06b INVESTIGATING THE PERFORMANCE OF GROUND ANCHOR THROUGH THE FAILURE SLOPE DISASTER IN TAIWAN by Jeng, Ching-Jiang and Chen, Yen-Cheng. This paper describes a slope failure or landslide which occurred in April of 2000 along the Formosa Freeway in Northern Taiwan. The authors discuss at length the two key factors, which were determined to be the primary mechanisms associated with the failure of the slope. The first mechanism is described as a softening of a thin interlayer between a sandstone and shale layer and the second mechanism is ground anchor corrosion. Subsequent sections of the paper discuss not only the ground anchor corrosion on this project but also expand to discuss a comprehensive survey previously implemented for ground anchors on slopes along several freeways. A life cycle maintenance management program for permanent ground anchors is illustrated in the paper and a graph showing the relationship between anchor performance and design service life is provided. Numerous examples of corrosion of ground anchors are shown to illustrate potential failure mechanisms. Techniques for enhancing the long term performance of the ground anchors and minimizing the potential for future corrosion type failure mechanisms of ground anchors are described in detail in the conclusions.

Paper No. 3.07b: THE SIMPLIFIED KZP6 METHOD FOR TIEBACK WALL DESIGN IN GRANULAR AND COHESIVE SOILS by Kumars Zand-Parsa & Kamran Zand-Parsa. The paper illustrates a method to calculate the embedment depth and the corresponding global stability safety factor of tieback walls with maximum 20 m height and with one to four levels of anchors using equilibrium equations. An illustrative calculation example is presented and results are compared with the solution of other calculation techniques.

Paper No. 3.08b: A CASE HISTORY OF DEEP EXCAVATION IN DOHA by L. Tony Chen. The paper deals with the construction of the Doha high-rise tower (45 stories, 232m high above the ground and 4 level basement, with a footprint area of approximately 16,000 square meters). The main concern is about the 16 m deep excavation and its temporary support. The paper describes the soil geological, geotechnical and groundwater conditions. The paper also illustrates the temporary support design which consists of "Anchored secant pile wall with toe grouting" and the construction stages. During construction excessive movements have been observed. In particular, when the excavation reached the level of about -13.5m, excessive lateral wall movement was detected on part of the southern wall. Within a couple of days, the measured wall deflection had reached about 80mm which was significantly greater than the design limit of 25mm. This is a good example of application of the so – called observational method. A subsequent investigation found that the excessive wall movement had been caused by some loosened ground anchors. In order to check the structural condition of the moving piles, it was necessary to estimate the maximum pile responses induced by the measured wall movement. Such a check may be undertaken using either numerical methods or published design charts as discussed in Chen & Poulos (1997, 1999, 2001) and Poulos & Chen (1996a, 1996b). Because of time restriction the use of design chart was adopted. The remedial measures adopted consisted of: interruption of excavation, backfill of the excavation up to – 10 m, restressing of the loosened anchors and installation of a strutting system. This last caused some inconvenience for the completion of excavation and basement construction but was necessary to avoid additional wall movements.

Paper No. 3.09b: A CASE HISTORY OF A DEEP FOUNDATION PIT CONSTRUCTED BY ZONED EXCAVATION METHOD IN SHANGHAI SOFT DEPOSIT by Z. H. Xu, J. Zhang & C. Chen. The paper presents a well-documented case history of monitored deep excavation for building foundation in Shanghai soft deposit. The excavated area was about 15916 square m with an excavation depth of about 15 m. The paper provides a well detailed soil characterization. Around the excavated pit, there existed many facilities including roads, the shield tunnels of the No.7 Metro, buildings, and pipelines. Zoned excavation method was adopted in this project. The excavation was divided into a relatively small pit (Zone I) and a big pit (Zone II). The small pit was just adjacent to the tunnels. The small pit and the big pit were separated by temporary diaphragm walls. Both pits were constructed by bottom-up method (firstly the small pit and after the big pit). An extensive instrumentation program was carried out to monitor the performance of the excavation and the adjacent facilities. The monitored data of the retaining structure and the surrounding facilities were analyzed. Observed results show that zoned excavation method was effective in controlling the deformation of the adjacent tunnels.

Paper No. 3.11b: APPLICATION OF JACKET PACK ANCHOR (JP ANCHOR) by Tae-Seob, Kim & Yoon-Ju, Cho. The paper mainly deals with the technology and applicability of Jacket Pack Anchors. Some existing data on case histories in Korea concerning the use of this technology are summarised. The data include soil type, groundwater level and type of application.

Paper No. 3.15b: DOUBLE CASE OF PASSIVE PRESSURE ACTING ON WALL ROTATED ABOUT THE TOP by Petr Koudelka. The paper illustrates the facility developed at the Czech Academy of Sciences for basic studies on the active and passive pressure on walls as a consequence of a given kinematics. The experimental study concerns granular non cohesive materials. The facility has been developed in a number of years with improvement and modifications which are illustrated in the paper. The main objective is to proof the

mobilization of active and passive pressures as a consequence of wall movements. The wall movements are actuated under constant rate of displacement (possible application of different values) under PC control. The pressures behind the wall are monitored at different wall heights. The maximum displacement is of about 300 mm for active and passive pressures (1000 mm is the wall height). The main conclusion concerns the observation that rotation around the top does not fully mobilize passive pressure. In previous experiments it was observed the vanishing of pressures with time but creeping of granular soil has not been modeled. Eventually the Author states the need for revision of Eurocode 7 prescriptions.

Paper No. 3.16b: EXPLORATION, DECONSTRUCTION, AND REPAIR OF A DISTRESSED MSE RETAINING WALL IN SAINT PAUL, MINNESOTA by Joseph G. Bentler. This paper discusses the forensic analyses employed to understand the mechanisms that resulted in settlement above the 11-ft high MSE retaining wall and the mitigation measures employed. This paper highlights the increasing risk to designs based on laboratory test data that was not specific to this project, the importance of cross-checking laboratory results with borehole logs and site information. In this case study there appears to be a catalogue of foreseeable errors starting with insufficient site specific laboratory data to no site supervision by a geotechnical engineer, until indications that the structure was failing and then the services of an independent geotechnical engineer were employed. Following remediation measures the MSE wall has performed as expected and the author notes lessons learnt from the project.

Paper 3.17b FAILURE INVESTIGATION AND RESTORATION OF TWO CELLULAR SHEETPILE STRUCTURES by Frank M. Clemente, Jr. This paper describes a partial failure of one of the interconnected cellular sheetpile structure islands (designated as the New Jersey Island Structure), which supported a 332-foot-high steel latticed tower facilitating support of the Trainer – Delco Tap – Mickleton 220-38 kilo-volt transmission lines crossing the Delaware River. The author describes in detail the failure investigation and concludes with a failure hypothesis suggesting a progression of events occurred over time, which eventually resulted in the failure. Some of the contributing factors to the failure are described and included: scour and loss of sheet pile embedment, damage of sheet piles during installation, the presence of soft sediments and periodic backfilling of the cells, differential water pressure, increase of internal earth pressure and hoop tensile stress, and excessive circumferential stress and interlock failures. The other interconnected cellular sheetpile structure (designated as the Pennyslvania Island structure) exhibited early signs of potential failure, which was not in as a severe condition as the New Jersey Island structure, requiring assessment and rehabilitation, as well. The selected rehabilitation is discussed in detail and included backfilling the depressions with lightweight fill, repairing of the cathodic protection and placement of a waterside crushed stone, buttress in combination with a riprap armoring. Rehabilitation of the Pennsylvania Island structure is also discussed. The author concludes with emphasizing the importance of inspection, assessment, rating, maintenance and effective early repair specific to the potential adverse impacts of scour around structures in waterways.

Paper No.3.18b: FAILURES OF RETAINING WALL STRUCTURES DUE TO EARTHQUAKE by Mohammadreza Abbasi Garavand & Hamzehlou Bahareh. The paper mainly deals with the numerical prediction of fracture zone in cantilever reinforced concrete retaining walls subjected to earthquake motion. The Authors carried out 3D numerical analyses by using the program ANSYS 11. As for the seismic input, accelerograms registered during Kobe, Northridge and Chichi earthquakes have been used. The Authors classify the appearance of cracks in the wall into two categories (flexural and tension cracks in the face and compression and flexural cracks in the foundation)

Paper No. 3.19b: Accumulation of Rainfall in the Permeable Fill behind a Soil Nail Wall by S. Mohsen Haeri, Mohammadhasan Sasar & Kioumars Afshari. The paper deals with the tension crack induced behind a deep excavation in the cemented subsoil of Tehran realized to construct 4 basement levels of multiple buildings within a very urbanized area. Excavation extended down to a maximum depth of 16.5 m and was supported by soil nailed wall. The construction technique of the soil nailed wall is described in detail, as well the monitoring system. The authors assume that the crack was induced by the presence of fill not properly compacted, not cemented as the natural soil and more permeable of the natural soil. This fill was originated by leveling of the area, for urbanization purposes, since the late sixties. Anyway the main cause of the crack was a prolonged period of raining (three - day rainfall) and inappropriate location (too low not intercepting the more permeable fill) of the drainage system behind the soil nailed wall. The prolonged period of raining has not been accounted for in the project because it was supposed that the excavation should have a very short duration. Adopted countermeasures are not illustrated in detail.

Paper No. 3.20b: LESSONS LEARNED FROM THE DISASTER AT LIPPE CANAL BRIDGE by Markus Herten & Eva Dornecker. During construction works at the new Lippe canal bridge, massive water leakage from the canal occurred below a wing wall into an excavation pit. This paper focuses on the verification against hydraulic heave and erosion of the excavation pit adjacent to the pile-supported wing wall. The authors note that Terzaghi's recommendations are still as relevant today as they were when he wrote them, Unfortunately due to the legally binding agreement between the owner and contractor, at this point in time, the full findings and outcomes leading to the failure cannot be reported. It would be very interesting to have a second paper once these findings are allowed to be made public.

Paper 3.21b: MITIGATION OF SEISMIC DEFORMATION OF ACHORED QUAY WALL BY COMPACTING by Pooyan Ghasemi, Abbas Ghalandarzadeh, Ashraf Zekri & Mohammad H. Aminfar. This paper describes the numerical modelling and physical modelling, via shake table, of an anchored sheet pile wall or anchored quay wall at Rajaii Port in Iran. The numerical and physical modeling is utilized to substantiate potential failure mechanisms of the anchored quay wall and determine zones for improvement relative to wall stability. The authors conclude that the main mechanism for deformation of the system is the presence of a liquefiable zone of material at the root of the wall during an earthquake. The numerical and physical modeling are utilized as a means of predicting lateral wall displacements and displacements of the backfill material with and without the suggested improvement. The authors also conclude the most deformable zone of material is located adjacent to the root of the wall and the performance of the concrete tie-back system is problematic as a result of displacement of the backfill material due to liquefaction.

Paper 3.22b: STABILIZATION OF EXISTING SHEET PILE CELL IN THE OHIO RIVER by David W. Bird. This paper describes the stabilization system implemented for a 40-ft-diameter sheet pile cell, which was initially designed and constructed in 1986, to support a dry fly ash loading platform on the Ohio River in West Franklin, Indiana. The stabilization system was implemented prior to putting the sheet pile cell into use as the cell was observed to lean towards the river several inches years after construction and subsequent overturning analyses indicated the factor of safety was less than adequate without the future anticipated platform loads. The existing cell was to be used as part of a dry fly ash conveying system and supports portions of the conveyor and the fly ash loading platform. The authors describe at length the remedial system design and construction procedures, which included the implementation of a 750,000 lbs horizontal stabilizing system. The stabilization force was applied by constructing a tension belt steel channel bent around the cell circumference connected to two-1-¾-inch-diameter, high-strength tension bars at each end. The horizontal stabilizing force was achieved on the landside of the cell by utilizing four-200-ft-long rock anchors installed in each pile cap, which are supported by a tripod of three-120-ton, HP 14 x 117 piles driven on a 4:1 batter. The authors describe unique compatibility of deformation issues associated with the elongation/deformation of the tension bars, rock anchors and pile caps, which were addressed through a detailed load testing and lock-off procedure, as well as the overall construction procedures to implement the stabilization system.

Paper No. 3.25b: RECONSTRUCTION OF A DETERIORATING, TIERED, MSE WALL STRUCTURE IN CONNECTICUT by Matthew E. Meyer, Christian B. Woods & Neritan Axhushi. The paper describes the investigation, design, and construction methodologies that were implemented to provide an economical solution to a multi-tiered Mechanically Stabilized Earth (MSE) retaining wall system that was constructed in the early 1990's to mitigate long-term wall stability issues. Several options were evaluated and conceptual designs were developed by the authors to achieve a cost efficient design to stabilize the walls and slope.

Paper No. 3.26b: PREVENTION OF ADDITIONAL BUILDING SETTLEMENT DUE TO ADJACENT CONSTRUCTION AT ST. FRANCIS HOSPITAL AND MEDICAL CENTER IN HARTFORD, CT by Giuliana Zelada-Tumialan, William P. Konicki, Sean D. Radley & Drew Floyd. The paper presents the design, monitoring, and construction considerations for jacked pile underpinning of a portion of a building, a cross lot braced soldier pile and lagging excavation support system adjacent to the building, and micropiles to replace driven H piles specified for the a Tower foundation in the immediate vicinity of the building, all selected to minimize additional damage to the adjacent building. The building, which provided critical laboratory, pharmacy, and administrative support functions to the hospital, was evaluated and the cause of movement determined. The authors illustrate the results of the forensic investigation and condition assessment of the distressed building as background for a detailed discussion of the alternate construction processes implemented to control further movement.

Paper No. 3.28b: 3D FEM MODELLING OF A DEEP EXCAVATION CASE HISTORY CONSIDERING SMALL-STRAIN STIFFNESS OF SOIL AND THERMAL SHRINKAGE OF CONCRETE by Yuepeng Dong, Harvey Burd, Guy Houlsby & Zhonghua Xu. The paper presents an interesting comparison (back analysis) between field measurements and numerical 3D analyses of a top-down deep excavation in Shanghai. The numerical analyses were performed with ABAQUS and the effects of different soil constitutive laws and of thermal shrinkage of some structural elements on the predictive performance of the numerical model were investigated. The numerical results captured the excavation behaviour and soil response, and reproduced the field measurements well. In particular, the soil constitutive law with strain-dependent stiffness was found capable to reproduce the response of the soil (horizontal and vertical movements) around the excavation. The results showed that small-strain soil stiffness is crucial to describe the excavation behaviour and the thermal shrinkage of some concrete elements should not be neglected in deep excavation problems.

Paper No. 3.30b: BLOOMFIELD ROAD STORMWATER STORAGE TANKS GROUTING WORKS, BLACKPOOL, UK by Mark Edmondson, Pamela Rigby, David Jones & Elizabeth Gallagher. The paper describes a storm water storage tanks (two buried tanks) that have been constructed in 1999 in Blackpool UK. Anyway, significant groundwater inflows with minor fines content have been observed since 2001. The phenomenon concerned one of the two thanks. From 2008 an increase of fines ingress has been observed indicating potential for progressive failure of the underlying

formation strata. An innovative event tree risk analysis tool was developed to identify and allow a focused remedial works design and a cost effective solution to be planned. The main works implemented comprised: sealing of the base slab joint by resin injection; contact grouting beneath the base; ground investigation works including cross hole tomography geophysics; and grouting within the Mudstone formation.

Paper 3.32b CASE STUDY ON THE REHABILITATION OF A DISTRESSED RETAINING WALL by G L Sivakumar Babu, Pawan Kumar & Raja Jaladurgam. This paper describes analyses which substantiate the suggested rehabilitation of a distressed retaining wall for a bypass roadway is effective to increase factors of safety, which were less than permissible. The analyses were primarily performed utilizing the finite element approach with the computer program PLAXIS. The authors present the results of limit equilibrium analyses and show the factor of safety against sliding to be the most critical relative to the existing completed conditions prior to rehabilitation. Results of FEM analyses indicated both overturning and sliding failure mechanisms were critical, especially with respect to the water table location. Distressed conditions were evident of the existing completed retaining wall. The authors concluded the results of the FEM method were superior to conventional techniques and approximated the actual factors of safety better, as there was observed distress of the completed retaining wall. The authors also concluded the soil nail system would serve as a satisfactory rehabilitation system for the distressed retaining walls. Due to the narrow nature of the central fill, the authors suggest it may be easier to implement soil nails in a connected manner as opposed to staggered nail arrangement. An interesting discussion item would be whether it is easier to perform rehab-type construction from the outside of the wall by drilling soil nails through the face of the existing walls or excavating the central fill to facilitate connection of the soil nails at their approximate mid-point. Also an interesting discussion item would be the behavior of the soil nails in their traditional sense compared to the more rigid, structural behavior of a connected continuous soil nail from wall face to wall face as illustrated as an alternative nail arrangement in the paper.

Paper No. 3.34b: REMEDIATION OF DISTRESSED FROZEN EARTH COFFERDAMS by Joseph A. Sopko & Robert Chamberland. The paper presents artificial Ground Freezing method that was used to provide temporary earth support and high groundwater velocity control for a complex system of three frozen earth cofferdams for the Milwaukee Metropolitan Sewer District's Harbor Siphons Project in Milwaukee, Wisconsin. Site geometry and frozen earth structural design precluded construction of one large excavation, requiring the component system of the tangential cofferdams. Ultimately a more aggressive ground freezing program was implemented and the project was successfully excavated.

Paper No. 3.35b: SOME REMARKS ON THE INFLUENCE OF DEEP EXCAVATIONS ON NEIGHBOURING BUILDINGS by Cătălin Căpraru & Anton Chirică. The paper is very interesting and summarizes the results of a parametric study carried out considering an ideal geotechnical model of deep excavation, typical of Bucharest (Romania) subsoil. The analysis of the excavation was carried out using the finite element method. The adopted constitutive model was calibrated essentially to model unloading processes. On the other hand, the most important factors which affect the influence zone of the excavation (excavation depth, excavation width, distance to neighbouring buildings, and the weight of the neighbouring buildings) are shortly described and their importance on estimating the displacements of the retaining structure are discussed on the basis of the FE analysis results. The variation of influential factors to be considered in the parametric study was inferred from the analyses of 323 real case histories in the urban area of Bucharest.

Paper No. 3.36b: A CASE STUDY ON THE USE OF FLEXIBLE EARTH RETAINING STRUCTURE IN INSTABLE SLOPES by H. Turan Durgunoglu, Ahmet Sahin & Onder Akcakal. The paper deals with the problem of slope stabilization for infrastructure construction having the constrain of limited excavation volumes. This problem rises in urbanized areas and in cases where the geological conditions require stabilization along very steep slopes. The paper validates against a given case history a recently proposed method which uses both soil nailing and reinforced earth. The case history is from Baku Azerbaijan and monitoring of wall movements after construction positively verify the proposed methodology. It is worthwhile to remark that the problem of reduced length of reinforcement has been addressed by various researchers with various satisfactory proposals.

Paper No. 3.37b: EMBANKMENT SLOPE STABILITY ANALYSIS OF DWIGHT MISSION MINE SITE RECLAMATION PROJECT by Christopher, D. Kiser & Prabir K. Kolay. The paper deals with stability analyses of a proposed embankment within an abandoned coal mine near Sallisaw Oklahoma. The analyses have been carried out in the framework of a reclamation project supported by the U.S. Department of Interior which intends to grade and cover existing coal mine spoil piles, eliminate exposed high-wall segments, stabilize the slopes of a hazardous water body and vegetate an existing abandon coal mine site in Sequoyah County, Oklahoma The embankment, as designed, consists of a central clay core, mine spoils and a silty - clay material cap. A parametric study was accomplished by considering various geometries of the embankment and also different composition of the embankment. The ultimate goal was to determine the factor of safety (FS) for each variation.

SUMMARY OF RESEARCH PAPERS (3c)

Paper No. 3.02c: RESTORATION OF THE MILITARY CLUB BUILDING IN SOFIA, BY MICRO PILE INJECTIONS by Chavdar Vassilev Kolev. The paper illustrates the restoration works of a historical building in Sofia (Bulgaria), a brick structure (Military club from XIX century) damaged after underground works for the subway construction. Unfortunately, the reasons of the cracks appeared in the brick wall are not well explained and it is not clear if have been induced by deep dewatering or soil movements due to the mobilization of active pressure on the underground wall. The hydraulic conditions (aquifers and aquitards) before and after tunnel construction are not clearly illustrated as well the geotechnical conditions of the subsoil. The sequence of micropile injections and their effects on cracks have been monitored.

Paper No. 3.03c: CASE STUDIES OF DEWATERING AND FOUNDATION DESIGN: RETAIL WAREHOUSE IN TAIWAN by Barry S. Chen and Roy E. Jensen. This paper compares three retail warehouse sites in Taiwan that have high groundwater tables in common but drastically different soil conditions. The author demonstrates the benefit of assessing each site individually and to challenge established practices. Due to extensive geotechnical and hydrological explorations and testing more cost effective solutions were used in the final design. It is becoming common practice to consider sustainability and carbon accounting as part of construction projects, including the re-use of 'grey' water. It would be interesting for the authors to provide a second paper on these case studies to discuss how and where the drainage water was discharged, and to compare the carbon footprint of the long-term operation and maintenance of the pumping system to the alternative method of tie-down piles and watertight bathtub structures.

Paper No. 3.04c: GEOTECHNICAL ISSUES IN STRUCTURAL STABILIZATION OF HISTORICAL MONUMENT - CLOCK TOWER by Vlatko Sesov, Julijana Cvetanovska & Kemal Edip The paper illustrates the geotechnical investigations and numerical analyses carried out to assess the safety factor of a 30 m high clock tower in Macedonia resting on a hexagonal base and constructed in the XIX century. The first 24 m of the tower structure consists of massive stone masonry. A timber structure extends from about 24 m to the top of the Clock Tower. The size of the foundation is not given in the paper but the Tower looks very slender. The geometry of the encased Tower foundation is not well known, nonetheless the number of investigations carried out. Actually the Tower is leaning of about 2° westwards. As for the geotechnical investigation the sequence is only given without details on the results. The proposed solution is based on the enlargement of the foundation and the use of piles. The beneficial effects of such an increase of the foundation stiffness are evaluated by Finite Element Method (Plaxis) comparing the safety factor before and after the foundation enlargement under both static and dynamic conditions. Dynamic actions are defined as equivalent forces according to the local regulations.

Paper No. 3.05c: CONSTRUCTIVE SOLUTIONS TO THE CONSERVATION OF CULTURAL HERITAGE by Miroslav Todorov. The paper briefly illustrates the relevance of Bulgarian historical heritage and concentrate on some specific topics related to the preservation and retrofitting of masonry buildings. More specifically the degradation of the construction materials, the effects of settlements and related philological aspects are considered. The paper presents some specific approaches for the design of restoration works which respects the original construction (philological aspects).

TOPICS FOR DISCUSSION

Some specific discussion topics have been indicated at the end of individual summaries of some papers. More generally it seems interesting to focuses on the following general topics, as far as failure and remediation treated in Session 3 are concerned:

- capability and limitations of geotechnical investigations to avoid failures;
- capability and limitations of geotechnical investigations to explain failures after their occurrence;
- role of monitoring systems (observational method) to avoid or limit the negative effects of design or construction mistakes;
- role of monitoring systems to evaluate the effectiveness of adopted countermeasures;
- capabilities of numerical methods to assist the design of countermeasures
- effects of climate changes on the evaluation methods of slope stability;
- evaluation of durability of adopted countermeasures and of existing constructions;
- role of Guidelines and Building Codes.