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General Report — Session 4

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Fifth International Conference on
Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics
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GENERAL REPORT - SESSION 4

4a. Liquefaction and Seismically-Induced Settlement, Ground Failures, and Seismic Studies on Recent Earthquakes

4b. Stability and Displacement Performance of Slopes, Landfills, and Earth Dams Under Earthquakes

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INTRODUCTION

This General Report presents a summary of the 81 papers accepted for the Session 4 of the 5th International Conference on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics, held in San Diego, CA. The session was divided into two parts: Part A includes papers on liquefaction and seismic-induced settlement, ground failures, and seismic studies of recent earthquakes. Part B includes papers on the stability and displacement performance of slopes, landfills, and earth dams under earthquakes.

The papers originate from 24 countries and discuss important topics in the area of geotechnical earthquake engineering. Related to liquefaction and its consequences the topics varied in the following categories: laboratory testing, numerical modeling, DEM, silt and clay mixtures, mitigation strategies, in-situ testing, and recent earthquakes. The papers related to slopes, landfills, and dams can be divided in the following topics: sliding-block analysis, non-linear response, residual strength, probabilistic methods, embankments and levees, geometric effects, landslides, and recent earthquakes. A list of the papers for the topics related to liquefaction and slopes are listed in Tables 1 and 2 respectively, organized by country, authors, and paper title and number. The summaries include in this general report provide the reader with a general overview and focus of the paper, which is intended to direct the reader to areas of interest. Session 4 will also host a Discussion Panel led by leaders in the field.

The Session 4 co-reporters and organizers greatly appreciate the efforts of the authors in sharing their work with others in the profession. The general co-reporters were selected from scholars and professionals from different countries to add to the international perspective of this important conference. They all acknowledge the assistance of the conference chairman, staff, and their contributors.

Table 1. Session 4a: Liquefaction and Seismically-Induced Settlement, Ground Failures, Seismic Studies of Kobe, Lima Peru, Chile, Pakistan, China, U.S. and other Recent Earthquakes, Spatial Liquefaction

Country	Authors	Title and Paper Number
India	Singh, Roy	Residual Shear Strengths of Cohesionless Soils from Energy Approach 4.01a
India Australia	Sitharam, Ravishankar, Vinod	A Note on the Effect of Non Plastic Fines on the Liquefaction and Reconsolidation Volumetric Strain Behavior of Sands 4.02a
USA	Weber, Bredikhin	Static Load Induced Liquefaction, Steels Corners Road Embankment Failure 4.03a
USA	Robertson, Shao	Estimation of Seismic Compression in Dry Soils using the CPT 4.05a
Taiwan	Kuo, Chang	Verification of Potential Flaws in Computing Liquefaction Potential Index by 1999 Chi-Chi Earthquake in Taiwan 4.07a
Iran	Naeemifar, Yasrobi	A Study of Effective Factors on the Behavioral Characteristics of Clayey Sands 4.08a
Greece	Papathanassiou, Valkaniotis , Pavlides	Assessment of Liquefaction Susceptibility of Geological Units in the Area of Gulf of Corinth, Greece 4.09a
USA	Liao, Mayne	Estimating Seismic Parameters Associated with Previous Earthquakes by SCPTU Soundings in the NMSZ 4.11a
Canada	Seid-Karbasi, Byrne	Optimum Depth of Seismic Drains for Mitigating Large Deformations in Liquefied Ground With Hydraulic Barrier 4.13a
Taiwan	Kung, Lee, Tsai	Examination of Existing DMT-Based Liquefaction Evaluation Methods by Site-by-Site DMT and CPT Tests 4.14a
Italy	Porcino, Marcianò	CPT Liquefaction Resistance Correlation of a Calcareous Sand Based on Calibration Chamber and Cyclic Simple Shear Tests 4.15a
India	Pathak, Dalvi, Katdare	Earthquake Induced Liquefaction Using Shake Table Test 4.16a
Egypt	Salem, ElZahaby	Application of General Regression Neural Networks (GRNNs) in Assessing Liquefaction Susceptibility 4.18a
India	Bhattacharya, Mukherjee, Das	Prediction of Liquefaction Potential for Kolkata Region by Semi-Empirical Method 4.19a
USA	Torres	Ground Motions and Liquefaction 4.20a
India	Rangaswamy, Boominathan, Rajagopal	Undrained Response and Liquefaction Behavior of Non-Plastic Silty Sands under Cyclic Loading 4.21a
Italy	Facciorusso, Uzielli, Vannucchi	CPT-based Comparative Mapping of Liquefaction Hazard for Large Areas 4.23a
Turkey	Cetin, Unutmaz, Bilge	Assessment of Liquefaction-Induced Foundation Soil Deformations 4.25a
Italy	Castelli, Lentini	SPT-Based Evaluation of Soil Liquefaction Risk 4.26a
Turkey	Pelin, Kutay	Numerical Modeling of Liquefaction in Layered and Silt Inter Layered Sands 4.27a
USA	Farrell, Wallace, Ho	Liquefaction Mitigation of 3 California Projects 4.28a
USA	El-Shamy, Zeghal, Dobry, Abdoun, Thevanayagam, Elgamal	DEM Simulation of Liquefaction-Induced Lateral Spreading 4.30a
USA	El-Shamy, Denissen	Microscale Characterization of Energy Dissipation Mechanisms for Evaluation of Liquefaction Potential 4.31a
Japan	Yoshida, Miyajima, Numata	Liquefaction Countermeasure Technique by Using Logs for Carbon Storage Against Global Warming 4.33a
Turkey	Oral, Cetin	Effective Stress Based Numerical Assessment of Liquefaction-Induced Landslide at Degirmendere Cape, Izmit Bay During Kocaeli (Izmit)-Turkey Earthquake 4.34a
Pakistan	Mahdi	Seismotectonic Contours of Kashmir-Hazara Regiona and Seismological Aspects of October 08, 2005 Earthquake 4.36a
Iran	Jafarian, Baziar, Sadeghi, Vakil	Probabilistic Evaluation of Field Liquefaction Potential Using Relative State

		Parameter Index (ξ_R) 4.37a
Iran	Bahadori, Asadzadeh	Evaluation of Gravel Drains Effectiveness Against Liquefaction in Shaking Table Utilizing Energy Method 4.38a
USA	Camp, Camp, Andrus	Liquefaction Mitigation Using Air Injection 4.39a
USA	Olgun, Martin II, Sezen	Field Evidence and Laboratory Testing of the Cyclic Vulnerability of Fine-Grained Soils during the 1999 Kocaeli Earthquake 4.41a
USA Peru	Meneses, Alva, Cox, Moreno, Olcese, Sancio, Wartman	Case Histories of Widespread Liquefaction and Lateral Spread Induced by the 2007 Pisco, Peru Earthquake 4.43a
Greece	Valsamis, Bouckovalas, Dimitriadi	Parametric Investigation of Lateral Spreading in Free-Face Ground Formations 4.45a
Serbia	Hadži-Niković, Perkovic, Abolma	Assessment of Liquefaction Potential Relevant to Choice of Type and Depth of Foundations in Seismically Active Areas 4.47a
USA	Liao, Meneses, Ortakci	Comparison of Three Approaches for Evaluating Earthquake-Induced Soil Liquefaction Potential 4.48a
USA	Naesgaard, Byrne	Back-Analysis of Upper and Lower San Fernando Dams Using a Combined Effective Stress – Total Stress Numerical Model 4.49a
Pakistan	Mahdi	Some Seismological Characteristics of Mw 6.5 Pishin-Ziarat October 29, 2008 Double Earthquake 4.50a
Australia New Zealand	Baki, Lo, Rahman	Cyclic Instability Behavior of Sand-Silt Mixture Under Partial Cyclic Reversal Loading 4.52a
New Zealand	Rahman	Equivalent Granular Void Ratio and Behaviour of Loose Sand with Fines 4.53a
Iran	Hesseini, Pisheh, Nia, Ganjian	Effect of Density on Critical Depth of Liquefaction in a Soil Deposit Containing Double Loose Sand Lenses 4.55a

Table 2. Session 4b: Stability and Displacement Performance of Slopes, Landfills and Earth Dams Under Earthquakes

Country	**Authors**	**Title and Paper Number**
India	Sengupta, Giri	Behavior of Nailed Steep Slopes in Laboratory Shake Table Tests 4.01b
Iran	Panah, Tavakol	Evaluation of Horizontal Seismic Coefficient for Embankments Based on Permanent Displacement 4.02b
Greece	Stamatopoulos, Thomaidis	Accuracy of Empirical Equations Predicting Sliding-Block Displacement 4.03b
Greece	Stamatopoulos, Mavromihalis	The Effect of the Geometry Changes on Sliding-Block Predictions 4.04b
India	Babu, Srivastava	Numerical Analysis of Failure of Rudramatha Dam Section During 26th January, 2001 Bhuj Earthquake 4.05b
USA	Arab, Kavazanjian	Nonlinear Time-Domain Analysis of a Sliding Block on a Plane 4.08b
Japan	Gratchev, Towhata	Geotechnical Characteristics of Seismically-Induced Aratozawa Landslide, Japan 4.10b
USA	Serafini, Perlea	Comparison of Liquefaction Triggering Analysis Approaches for an Embankment Dam and Foundation 4.12b
India	Goswami, Singh	Stability Analysis of Flood Protection Embankments and Riverbank Protection Works 4.13b
USA	Han	Seismic Analysis of the Reservoir-Earth Dam-Pore Fluid System Using an Integrated Numeric Approach 4.15b
USA Australia	Roth, Crouse, Dawson, Su, Hefer	Seismic Performance Evaluation of a Submarine Gas Pipeline 4.16b
India	Ghosh, Sarkar, Kanungo, Jain,	Slope Instability and Risk Analysis of a Slope with Human Habitation on Way to

	Kumar, Kalura	Uttarkashi, Uttarakhand, India 4.17b
Greece	Dakoulas	Response of a CFR Dam to Lateral and Longitudinal Vibrations Using a Refined Nonlinear 3D Numerical Analysis 4.18b
Romania	Chirica, Vintila, Tenea	The Stability and Deformation Limit State Corresponding to the High Road Embankments Close to a Bridge 4.19b
India	Roy	Design of an External Waste Rock Dump in an Opencast Coal Mine Standing Against a Hill in Seismic Prone Area of India 4.22b
UK	Foulser-Piggott, Stafford	Incorporation of the Spatial Correlation of Arias Intensity within Earthquake Loss Estimation 4.23b
So Africa	Theron, Wagener, Steenkamp	Seismic Stability Assessment the Raising of the Geita Tailings Storage Facility, Tanzania 4.24b
Italy France	Bozzano, Esposito, Lenti, Martino, Montagna, Paciello, Porfido	Numerical Modelling of Earthquake-Induced Rock Landslides: The 1783 Scilla Case-History 4.25b
USA	Gillette	Issues in the Use of Empirical Correlations for Estimating the Residual Undrained Shear Strength of Liquefied Soils 4.26b
India	Basudhar, Kameswara Rao, Bhookya, Dey	2D FEM Analysis of Earth and Rockfill Dams Under Seismic Condition 4.28b
Austria	Berhe, Wu	Effect of Canyon Geometry and Ground Conditions on the Seismic Performance of Tendaho Earthfill Dam in Ethiopia 4.29b
Japan	Ota, Takeya, Itoh, Kuraoka	Centrifuge Model Tests of Tieback Anchors and Drainage Pipes for Stabilization of Slopes Under Earthquake Loads 4.30b
Italy USA	Barani, Bazzurro, Pelli	A Novel Probabilistic Method for the Prediction of Earthquake-Induced Slope Displacements 4.31b
India	Waseem, Pratibh	Seismic Stability of the Nailed Slopes 4.32b
India	Bhat, Saxena	Static and Dynamic Behavior of Earthen Slopes in the Region of Uttarkashi, India 4.37b
USA	Lee, Green, Finch	An Empirical Predictive Relationship for Assessing the Seismic Stability of Slopes 4.39b
Japan	Nakai, Nagata, Sekiguchi	Effect of a Slope on the Dynamic Properties of Diluvial Terrace 4.40b
USA	Tiwari, Hillman	Seismic Slope Stability of Reactivated Landslides – A Performance Based Analysis 4.41b
Iran	Sakhi, Davoodi, Jafari	Using Recorded Earthquake Signals for Dynamic Analysis of Masjed Soleiman Embankment Dam 4.43b
Greece	Papadimitriou, Andrianopoulos, Bouckovalas, Anastasopoulos	Improved Methodology for the Estimation of Seismic Coefficients for the Pseudo-Static Stability Analysis of Earthdams 4.44b
USA	Mejia, Dawson	3D Analysis of the Seismic Response of Seven Oaks Dam 4.46b
Iran	Ghanbari, Mojezi, Fadaee	Seismic Behavior of Asphaltic Concrete Core Dams 4.47b
Iran	Komakpanah, Majidian	Assessment of Seismic Failure of Soil-Nailed Excavations Under Cyclic Load and Pseudo-Static Analysis 4.48b
Lebanon UK France	Abdel Massih, Soubra, Rouainia, Harb	Dynamic Slope Stability Analysis by a Reliability-Based Approach 4.51b
Iran	Malekian, Taghavi, Baziar	The Effects of Canyon Topography on Distribution Pattern of Dynamic Stresses in Earth Dams 4.52b
Japan	Bui, Fukagawa, Sako,Matsumoto	Earthquake Induced Slope Failure Simulation by SPH 4.53b

Japan	Yasuda, Mouri, Tsuruda	Cyclic Torsional Shear Tests to Obtain Dynamic Soil Properties for Seismic Design of Road Embankments 4.57b
Canada	Karimian, Wightman, Sriskandakumar, Yan	Soil-Structure Dynamic Analysis Using Scenario Target Spectrum Matched Records 4.58b
Norway	Vu Khoa	Finite Element Modeling of the Las Colinas Landslide Under Earthquake Shaking 4.61b
India	Koner, Chakravarty	Evaluation of Seismic Response of External Mine Overburden Dumps 4.63b
India	Pachauri	Landslide Hazard Mapping and Assessment in Himalayas 4.65b
Macedonia Serbia	Sesov, Zugic	Repair of Landslide "Umka-Duboko" – Seismic Performance Assessment 4.66b

SUMMARY REVIEW OF PAPERS

4a – LIQUEFACTION

Paper No. 4.01a: RESIDUAL SHEAR STRENGTHS OF COHESIONLESS SOILS FROM ENERGY APPROACH, by Raghvendra Singh and Debasis Roy. The residual shear strength of the non plastic soils are generally estimated from the correlations between residual shear strength estimated from the laboratory tests or from the back analyses of post failure geometries of case histories distressed during static or seismic loading and penetration resistances. The post failure shear strength of large deformed structures like debris flow, mud flow and avalanches in which the post deformed soil mass gain large distance after the failure, depends on the strain rate behavior of shear (viscous) resistance, frictional resistance, inertial effect, three dimensional effect of geometry, flexibility of failed material and void redistribution during failure. Therefore, in this paper an energy based procedure is proposed to estimate the residual shear strengths and based on the results of the back analysis of the post failure configuration of twenty cases the correlations between residual shear strengths and stress normalized and compressibility corrected Standard Penetration Test (SPT) blow counts and Cone Penetration Resistances (CPT) considering the energy based procedure are proposed.

Paper No. 4.02a: A NOTE ON THE EFFECT OF NON-PLASTIC FINES ON THE LIQUEFACTION AND RECONSOLIDATION VOLUMETRIC STRAIN BEHAVIOUR OF SANDS, by Sitharam, Ravishankar, and Vinod. This short paper discusses the influence of non- plastic fines on the liquefaction and reconsolidation volumetric strain behavior of sand based on the strain controlled cyclic triaxial experimental results. The investigations were carried out on sand samples collected from the earthquake-affected area of Ahmedabad city of Gujarat state in India. Laboratory investigations were conducted on clean sand (prepared from the natural sand) samples with varying amount of non-plastic fines. Experimental results highlight a considerable influence of non-plastic fines on the resistance to liquefaction and reconsolidation volumetric strains behavior during cyclic loading.

Paper No. 4.03a: STATIC LOAD INDUCED LIQUEFACTION, STEELS CORNERS ROAD EMBANKMENT FAILURE, by Weber and Bredikhin. The paper presented a very interesting and well-documented case history of embankment failure. The embankment was constructed for a roadway widening project with dimension 25-foot wide and 15-foot high. Part of the embankment failed producing 4 feet vertical and 1 feet lateral movement. The observed settlement is substantially more than the predicted 12-inch settlement. The project site has unique subsurface conditions with the glacial outwash deposits, which consist of alternating clay-rich and sand-rich, layered soil strata. This soil sequence is prone to develop artesian and/or perched water tables. The "sand" layer has a natural water content close to the liquid limit of the soil. The possible reasons for the embankment failure were evaluated and concluded that the failure was caused by the potential liquefaction of the "sand" layer due to the quick static loading and blockage of drainage path. Several ground improvement approaches including soil mixing, vibro-compaction and stone column were discussed. The wick drain was selected for the most cost effective. The installation of the wick drain could relieve the pore water pressure and stabilize the sand layer. The proposed remediation sounds very reasonable if liquefaction is the true reason of the failure. The piezometers were recommended for monitoring the pore water pressure in the "sand layer" during the installation of the wick drain. However, no piezometer monitoring data was provided to confirm the "quick sand" condition under quick static load (placement of fill). Additionally, the author should consider the impact of the compaction on the potential generation of excess pore water pressure in addition to quick static load.

Paper No. 4.05a: ESTIMATION OF SEISMIC COMPRESSION IN DRY SOILS USING THE CPT, by Robertson and Shao. The paper presented a simplified method to estimate earthquake-induced settlements of improved ground. The method by Robertson and Shao was developed through modifying the popular method presented by Pradel (1998). In this study, the Pradel method was extended to cover a wild range of unsaturated soils. A key parameter, the small strain shear modulus (G_0) which can be measured using the seismic CPT or estimated form the CPT, was adopted in the update of Pradel method. Also included in the developed method is a simplified method to consider the effect of "shear reinforcement" caused by the ground improvement such as the stone columns and compaction grouting columns. A ground improvement project in southern California is used to analyze the seismic compression settlement using the developed method. The proposed simple modification of the Pradel method provided a valuable tool to evaluate the effectiveness of the ground improvement work.

Paper No. 4.07a: VERIFICATION OF POTENTIAL FLAWS IN COMPUTING LIQUEFACTION POTENTIAL INDEX BY 1999 CHI-CHI EARTHQUAKE IN TAIWAN, by Kuo and Chang. The authors used the Liquefaction Potential Index (P_L) method for soil liquefaction potential assessment and prediction of induced damages at numerous locations in Taiwan and compared the results with damages observed following the Chi-Chi earthquake in 1999. This method was originally developed by Iwasaki and Tatsuoka in the early 1980's and is currently recommended by the Taiwanese Building Codes. P_L is evaluated for any individual boring based on field tests capable to determine the factor of safety (F_L) against liquefaction (e.g. SPT) and results from integration with depth of weighted $(1 - F_L)$ values, anywhere $F_L < 1$. The weight decreases linearly from a maximum value (20) at the ground surface to zero at the depth of 20 meters. The authors found that the liquefaction occurrence prediction was poor when compared to the actual observations in field and attributed this discrepancy to different conditions in Taiwan than in Japan, where the procedure was originally calibrated. They considered that a major source of error is the uneven distribution of the SPT's along a given boring. They recommended a modified procedure, which actually arbitrarily changes the assumption on variation of the factor of safety between two adjacent locations where they are known. In fact, both the original and the modified procedures failed to appropriately assess the liquefaction potential. For example, of the 1081 examined borehole logs with SPT, 27 had $P_L > 15$, which would signify very high liquefaction potential, but in only one case (3.7%) liquefaction was observed. On the other part, 979 locations had very low liquefaction potential (PL < 5) but in 43 of these locations (4.4%) liquefaction occurred.

Paper No. 4.08a: A STUDY OF EFFECTIVE FACTORS ON THE BEHAVIOURAL CHARACTERISTICS OF CLAYEY SANDS, by Naeemifar and Yasrobi. As in recent years liquefaction phenomena have occurred in sandy soils containing different amounts of clay contents, it was concluded that in addition to silty sands, clayey sands are also vulnerable to liquefaction phenomenon. So, the urge for comprehensive study aroused to cover the issue. In this paper, the effect of clay content and its plasticity properties on behavioral characteristics of clayey sands under various density and confining pressure values have been investigated. To achieve the goal, about a hundred monotonic triaxial tests were performed on remolded specimens of sandy soils containing different clay contents with different plasticity values. Based on the results, the latter factors affect peak strength, steady state strength, undrained brittleness and residual shear strength, considerably. It seems that steady state strength decrease for shallow sand specimens is more sensitive to clay content increase. Also it was concluded that denser specimens are more sensitive to any increase in clay content and their behavior changes much significantly. For lower clay contents, fines content governs behaviors. However as clay content increases, gradually the role of plasticity becomes more pivotal.

Paper No. 4.09a: ASSESSMENT OF LIQUEFACTION SUSCEPTIBILITY OF GEOLOGICAL UNITS IN THE AREA OF GULF OF CORINTH, GREECE, by Papathanassiou, Valkaniotis, and Pavlides. The authors report partial results of a five-year project, which was taken place at Aristotle University of Thessaloniki, Department of Geology. Its primary goal, achieved few years ago, was the collection of data regarding historical liquefaction occurrences and the compilation of a map showing the sites where liquefaction-induced failures were reported (Papathanassiou et al. 2005). The second goal of the project was the evaluation of the liquefaction susceptibility of deposits in Greece (scale 1:500.000) that was accomplished last year and presented by Papathananassiou et al. (2009). Specifically, in this paper they develop a map regarding the liquefaction susceptibility in the coastal area of Gulf of Corinth, Central Greece based on the data regarding the age and depositional process of sediments the value of peak ground acceleration (PGA) and the occurrence of historical liquefaction manifestation within the area. This map is based on the 1:50,000-scale mapping of geological units, historical surface evidences of liquefaction phenomena, and seismotectonic data. The main active and possibly active faults are situated at the southern Corinthian gulf with length up to 40 km. Within the study area large earthquakes occurred and triggered severe primary and secondary effects including liquefaction-induced ground failures. The resultant map can be used only as a screening guide for planning purposes since for the assessment of the liquefaction potential of the area, site-specific studies.

Paper No. 4.11a: ESTIMATING SEISMIC PARAMETERS ASSOCIATED WITH PREVIOUS EARTHQUAKES BY SCPTU SOUNDINGS IN THE NMSZ, by Liao and Mayne. The paper presents a methodology to determine seismic parameters (magnitude and PGA) from historic earthquakes. This methodology is verified using (2) locations known to have liquefied during the Loma Prieta earthquake, and it is subsequently applied to two (2) locations suspected to have liquefied during historic events in the NMSZ. The methodology considers using attenuation relationships for various magnitude events to determine a range of seismic demands. The methodology determines the yield acceleration (FS=1) at the limits of liquefaction from standard penetration or Vs data from a specific site for a range of earthquake magnitudes. All calculated data is presented on a plot of magnitude vs. PGA, and the intersection of the seismic demand versus the resistance corresponds to the specific earthquake parameters. Overall the paper presents a methodology that with further refinement could be useful, but in its present form there are too many issues with "unreasonable results" not discussed with the presented application. Both the application and resulting conclusions for the two sites analyzed are somewhat contrived, and the reliance on specific event parameters such as site to source distance and overburden pressures are approximate at best for historic events.

Paper No. 4.13a: OPTIMUM DEPTH OF SEISMIC DRAINS FOR MITIGATING LARGE DEFORMATIONS IN LIQUEFIED GROUND WITH HYDRAULIC BARRIER, by Seid-Karbasi and Byrne. The seismically induced ground deformations are often the main concern when liquefaction occurs in significant zones of an earth structure or soil foundation. Recent studies including field data, centrifuge model testing and numerical investigations indicate that large lateral spreads and flow-slides in gentle sandy slopes have taken place when a low permeability silt/clay layer (hydraulic barrier) is present. One of the promising measures to alleviate this barrier effect and ground failures is seismic drains. Currently, the effects of seismic drain configuration in plan are well understood and established in the engineering profession since the pioneering work by Seed and Booker (1977). Typically, most drain improvement schemes comprise of seismic drains that are fully penetrated in the liquefied soil layer for reducing the liquefaction potential and earthquake-induced deformations. The authors present a valuable point for designing the optimum depth of seismic drains for mitigating large deformations in liquefied ground with hydraulic barrier. The crucial literature in this research topic has been extensively reviewed and presented in this paper. The reader can completely understand the development of this topic. Seid-Karbasi and Byrne (2010) indicated that it is necessary to simulate the generation, redistribution, and dissipation of excess pore pressures during and after earthquake shaking in order to evaluate the impact of a low permeability layer on the earthquake-induced ground deformations. The coupled dynamic stress-flow analysis is required. The UBCSAND constitutive model developed by Byrne (1995) based on the elasto-plastic stress-strain model was used in this paper to investigate the effects of drain depth in mitigating the observed ground deformations through the numerical simulations and the comparison of past studies including centrifuge tests and physical model tests. The crucial conclusions include: 1) for a given configuration of seismic drains, the effectiveness of the drain system varies with the depth of drains, 2) Seismic drains have multiple effects on the response of liquefiable soil layers to earthquakes i.e., a. Dissipation effect, b. Facilitating flow within the medium. c. Alleviation of the base isolation effect of liquefied soil. The extent of improvement from drains installation reflects the interplay of the above effects. 3) Seismic drains with full penetration through the liquefiable layer are not the optimum measure in all cases. Drains with partial penetration are the optimum solutions for providing minimum deformations. They are also more cost-effective. 4) Drains with minimum penetration can be a promising economic measure for providing improvement. Generally, it is likely that the location of the sub-layers barrier is not known very well in which case some drains to greater depths would seem wise.

Paper No. 4.14a: EXAMINATION OF EXISTING DMT-BASED LIQUEFACTION EVALUATION METHODS BY SIDE-BY-SIDE DMT AND CPT TESTS, by Kung, Lee, and Tsai. This study employed the field measurements of flat dilatometer test (DMT) and cone penetration test (CPT) presented by a recent study (Tsai et al. 2009) and additional DMT and CPT data conducted in this present study to examine the existing DMT-based liquefaction evaluation methods. Specifically, the DMT and CPT were conducted side-by-side at each of six in-situ sites and thus it is feasible to incorporate those test results into validating the existing DMT-based methods such as Grasso and Maugeri (2006), Monaco et al. (2005), and Reyna and Chameau (1991). The DMT parameter, horizontal stress index (K_D), is used as an indicator for assessing liquefaction resistance of soils. The analysis results revealed that the existing K_D-based liquefaction evaluation methods would overestimate CRR of soils, which leads to overestimate the factor of safety against liquefaction. Also, the estimation of DMT-K_D values by using the CPT-q_c as well as the correlation between DMT-K_D and CPT-q_c proposed by the previous studies would be significantly less than field measurements of DMT-K_D. However, it should be noted that it is desirable to incorporate more field measurements to further verify this finding.

Paper No. 4.15a: EVALUATING LIQUEFACTION RESISTANCE OF A CALCAREOUS SAND USING THE CONE PENETRATION TEST, by Porcino and Marcianò. This paper presents an experimental study based on Static Cone Penetration Tests (CPT) performed in Calibration Chamber (CC) and cyclic Simple Shear (SS) tests was undertaken in order to establish a correlation for estimating cyclic resistance ratio (CRR) of calcareous sands. CPT's in CC were carried out on an uncemented calcareous sand, dug out from Brittany in France (Quiou sand) in the context of a previous research. Test results were thus re-analysed by the authors, considering the specific purposes of the paper. SS tests were conducted on specimens reconstituted by water sedimentation method that, according to the authors' previous studies is capable of reproducing more realistically than other methods, the in-situ response of natural deposits of marine or fluvial origin. Test results showed that CRR vs. normalized cone penetration resistance (q_{c1},N) data points fall just above correlation curves, recommended in the literature for the assessment of liquefaction potential of clean silica sands. The approach based on relative state parameter concept embodied in current semi-empirical liquefaction correlations was also verified for the tested sand.

Paper No. 4.16a: EARTHQUAKE-INDUCED LIQUEFACTION USING SHAKE TABLE TEST, by Pathak, Dalvi, and Katdare. The authors have studied the liquefaction of medium dense saturated sand using shaking table test and compared the test results with both field cases and published laboratory test results. A total of 12 tests were conducted on the different saturated sand samples with relative density ranging from 62 to 74 percent. Two sets of harmonic loading with frequency 2Hz and 3Hz were applied to each sand sample. The pore water pressure and acceleration are recorded with time during the testing. The test results were plotted on a CSR vs. number of cycle to initial liquefaction graph and were compared with available data in the literature. The present study shows a higher cyclic stress ratio (CSR) for the same number of vibration cycles. No apparent trend was found for the presented data. The paper explained the possible reason for the higher CSR was attributed for the confinement of the soil sample container, which made more number of cycles required to liquefy the soil under otherwise identical conditions. More tests including the samples with lower relative density and other frequency loadings are recommended for this study.

Paper 4.17a: RECENT ADVANCES IN LIQUEFACTION OF FINE GRAINED SOILS by S. Prakash and V. Puri (USA). The authors compiled a comprehensive history of changes during the last 30 years in concepts and procedures for the assessment of liquefaction susceptibility of fine grained soils. The original Chinese Criteria were successively modified to account for new case history and laboratory tests findings. The major role of the plasticity index among the factors controlling the liquefaction susceptibility was previously underlined by the authors, observing generally an increase in resistance to liquefaction with the increase of the plasticity index. However, laboratory tests, including some originally reported by the authors, indicated an opposite trend in the range of low plasticity indices of 2 to 4.

Recent case history evidences suggested that cohesive soils may be susceptible to significant strength loss in some circumstance of seismic action, even if they were considered non-liquefiable based on newer, improved criteria. The authors stressed that the plasticity index and not the percentage of fines can serve as better criterion for defining the liquefaction susceptibility of silts and clays. However, when evaluating the loss of strength in clayey soils under the seismic action, their overconsolidation ratio and sensitivity appear to play a determinant role. The authors consider that more work and time is needed for a good understanding of the fine grained soils liquefaction behavior.

Paper No. 4.18a: APPLICATION OF GENERAL REGRESSION NEURAL NETWORKS (GRNNS) IN ASSESSING LIQUEFACTION SUSCEPTIBILITY, by Salem and El-Zahaby. In this paper, a general regression neural networks approach (GRNNs) has been used to assess the liquefaction hazard in Egypt. Thus, data from new locations can be analyzed using GRNNs to obtain the liquefaction risk associated with this new site. The computer package "Neuroshell 2®" has been extensively used to build up the GRNNs models. A number of factors have been identified as the contributing factors to the assessment of liquefaction potential including: soil's relative density, pore pressure, overburden pressure, and SPT blowcount. It appears that the presented results are in their early stages as there was no conclusion whether the analyzed sites were susceptible to liquefaction or not. Also it was not clear how this approach is different from or more efficient than current conventional methods for assessing liquefaction potential.

Paper No. 4.19a: PREDICTION OF LIQUEFACTION POTENTIAL FOR KOLKATA REGION BY SEMI-EMPIRICAL METHOD, by Bhattacharya, Mukherjee and Das. Site specific correlations between cross-hole shear wave velocities and standard penetration test (SPT) N-values were established for a Deltaic deposit in India. Both correlations with field N-values and energy corrected N_{60}-values were determined, although only the latter make sense, as SPT results, if not corrected, are supposed to be obtained through the standardized energy. From the published data it is not clear if the missing exponent (0.25) in the definition of shear wave velocity normalization was a typo or the normalization of measured velocities was incorrectly done. There are some instances where the liquefaction assessment through shear wave velocity data has advantages and may produce more reliable results when compared with the more widely used method based on SPT (e.g. when the SPT data may be affected by occasional large gravel particles). This may be the case of the studied deposit, where the factors of safety determined based on the shear wave velocity using the Andrus and Stokoe (2000) criteria were significantly lower than those obtained through the traditional Seed and Idriss (1971) simplified procedure. However, the authors do not try to explain the discrepancies in results, but state that the results were similar in the upper 20 m of the deposit and that the factor of safety against liquefaction was underestimated below this depth when derived on the basis of shear wave velocity.

Paper No. 4.20a: GROUND MOTIONS AND LIQUEFACTION, by Torres. The paper examines the seismic response of an embankment dam built on a soil layer, considering the potential for liquefaction and strength loss. The earthfill dam retains a 60,000 acre-feet reservoir with a significant population downstream of the dam. The embankment is about 45.7 m (150 ft) high with a crest width of 9.1 m (30 ft), and is about 610 m (2000 ft) long, with slopes equal to 3:1 upstream and 2:1 downstream. Under static conditions the minimum factor of safety is equal to FS=1.49. A post-earthquake analysis performed by changing the strength of the foundation layer from peak values to residual values has shown that the factor of safety is 0.83, indicating that the critical slip surface may lead to catastrophic embankment failure with large deformations. In the study, a 500 years return period subduction earthquake was used to evaluate the effects of smaller earthquakes on the embankment. The earthquake has a peak horizontal acceleration a_h = 0.286g, peak vertical acceleration a_v = 0.214g, and predominant period 0.2s. The seismic analysis of the embankment determined the peak accelerations assuming that liquefaction and/or cyclic failure has not occurred. The deformations of the embankment during earthquake loading were computed based on equivalent linear analysis using the code QUAKE/W and the Newmark Method option. Results are presented in plots of the distribution of the peak horizontal and vertical acceleration within the embankment. The critical slip surface was used for the computation of the deformation. It was found that the maximum deformation corresponding to the minimum factor of safety of 1.49 is 0.4 m (1.3 ft), as shown in Figure 3. The author suggests that such deformation is large for an embankment with FS=1.49 under an earthquake with peak acceleration of only 0.21g, and attributes the high value to the high amplification that occurs in the natural frequency of the dam (T_1 = 0.31 s). It would be also useful to consider the magnitude of peak seismic shear strains in order to verify the initial assumption that liquefaction and/or cyclic failure has not occurred during shaking.

Paper No. 4.21a: UNDRAINED RESPONSE AND LIQUEFACTION BEHAVIOR OF NON-PLASTIC SILTY SANDS UNDER CYCLIC LOADING, by Swamy, Boominathan, and Rajagopal: This paper focused on the cyclic response of non-plastic silt and sand mixtures based on ground failure case histories after recent earthquakes (e.g. 1988 Saguenay, 1999 Kocaeli and Chi-Chi, 2001 Bhuj). Considering the contradictory results reported by various researchers, authors performed series of stress-controlled cyclic triaxial tests on laboratory reconstituted fine sand and silty-sand specimens having 30 % and 50 % non-plastic fines. The main findings of this experimental study can be summarized as; i) sand and sand-silt mixtures exhibit similar pore water pressure generation response; but pore water pressure built-up is significantly faster in sand-silt mixtures compared to clean sands, ii) increasing confinement pressure results in more contractive soil response for both clean sands and sand-silt mixtures; i.e., liquefaction resistance decreases and cyclic strains increase, iii) for constant relative density or void ratio, cyclic resistance of sand decreases with increasing non-plastic silt content up to 50%, and iv) cyclic resistance decreases linearly with increasing sand skeleton void ratio as the silt content increases. This study would have been more complete, if they had mentioned the effects of specimen preparation techniques and testing procedures since some of these contradictions stemmed from these issues.

Paper No. 4.23a: CPT-BASED COMPARATIVE MAPPING OF LIQUEFACTION HAZARD FOR LARGE AREAS, by Facciorusso, Uzielli, and Vannucchi. Liquefaction hazard mapping provides a useful tool for risk mitigation planning in seismic areas. An alternative approach of hazard mapping is proposed. Firstly, a zonation is performed on the basis of lithological, geological and seismic information. In such an approach, hazard zones, which can be considered homogeneous from a lithological and seismological point of view, are preliminarily contoured. Secondly, a hazard level, expressed in terms of exceedance probability of a threshold value of the liquefaction potential index, is then estimated for each zone. A cumulative index (LPI) which concisely parameterizes the liquefaction potential of sounded soils in terms of safety factor, FSL, or liquefaction triggering probability, PL, was defined and used for liquefaction hazard mapping. Two types of liquefaction hazard maps were produced in this study based on a case-study for a large coastal area of about 1300 km^2 in Central Italy, where data from 1325 CPT soundings covering an area are available. With reference to the illustrated case study, both types of mapping confirmed that the high hazard area for seismic liquefaction is limited to the Central and Southern coastal region, and that liquefaction hazard can be generally assumed to be low or locally moderate in the remaining spatial locations.

Paper No. 4.25a: ASSESSMENT OF LIQUEFACTION-INDUCED FOUNDATION SOIL DEFORMATIONS by Cetin, Unutmaz, and Bilge. This study indicates that contrary to the free field soil sites, liquefaction assessment of sites with super structures is a controversial and difficult issue. As such, assessing liquefaction triggering potential under building foundations requires the estimation of cyclic and static stress state of the soil medium. In this study, the proposed methodology for liquefaction triggering assessment of foundation soils by Unutmaz (2008) is discussed briefly. Then, the methodologies of Cetin et al. (2009) and Bilge and Cetin (2008), which were proposed to estimate strains for coarse and fine-grained soils, respectively, are used for validation of the methodology of Unutmaz (2008) through well documented foundation performance case histories of residential structures founded on liquefiable soils after 1999 Kocaeli earthquake. In addition to calibration and validation efforts, the validity of the following observations based on post earthquake reconnaissance, especially after 1999 Turkey and 1999 Chi-Chi earthquakes, is assessed. One of the cases located in Semerciler District, Adapazari, at Cark Avenue and studied after 1999 Kocaeli Earthquake was adopted to examine the proposed methodology proposed by Unutmaz (2008) for assessing the liquefaction-induced foundation soil deformations. The results showed that the simplified procedure proposed in Unutmaz (2008) is capable of capturing almost all of the behavioral trends and most of the foundation settlement amplitudes.

Paper No. 4.26a: SPT-BASED EVALUATION OF SOIL LIQUEFACTION RISK, by Castelli and Lentini. The authors describe in detail the Seed and Idriss semi-empirical procedure for evaluating the liquefaction potential of cohesionless soils during earthquakes and some Italian Code procedures for the selection of peak ground acceleration and characterization of sands from a liquefaction point of view. Evidence of liquefaction in the alluvial region of the Catania region of Sicily (Italy) was available for past earthquakes, both strong and moderate. The evaluation of the factor of safety against liquefaction through the SPT-based Seed-Idriss simplified procedure is considered by the authors an appropriate tool for microzonation of the studied area to define the risk of liquefaction and possible damage to structures.

Paper 4.27a: NUMERICAL MODELING OF LIQUEFACTION IN LAYERED AND SILT INTER LAYERED SANDS, by Pelin and Kutay. Modeling of liquefaction was accomplished using a constitutive model based on the multiple shear mechanism, which was implemented in the DIANA finite element program. The recorded motion from the shaking table test was used as the input motion for numerical simulation. It was found the computed excess pore water pressure matched with the experimental results expect for one of cases, in which the disturbance of the sand at the low depth was thought to induce inconsistencies. In order to investigate the effect of layered and silt inter layered sands on the generation of excess pore water pressure, the computed results were compared among the different cases, including uniform sands, silt inter layered sands, and layered sands. The results show that there is small amount of increase in computed excess pore water ratios for silt layered sand below the silt seam. For layered sands, the presence of overlying dense sand layer has an increasing effect on the excess pore pressures developed in the lower loose sand layer. This contradicted the results shown in experimental testing, in which high excess pore water pressure was developed in the upper dense sand layer due to the migration of excess pore water pressures from the bottom loose sand layer. It was indicated that the constitutive model used could not capture the migration of upward water flow. However, the computed excess pore water pressure ratios of layered sand model comprising of dense sand layers overlaid by loose sand layers are compared with the uniform sand model. This was reproduced in the experimental tests. It was concluded that the numerical simulation with multiple shear mechanism constitutive model can successfully predict the behavior observed in cyclically loaded uniform and silt inter layered sand, but a constitutive model coupled with a ground water flow analysis must be used for layered sand deposits. This paper applied numerical simulation to analyze the liquefaction and helped us understand the effect of the layered and silt inter layered sands on the excess pore water pressure.

Paper 4.28a: LIQUEFACTION MITIGATION FOR 3 CALIFORNIA PROJECTS, by Farrell, Wallace and Ho. This paper presents test data of the ground improvement sites using rammed aggregate piers (RAP) to control liquefaction. RAP provide the following ground improvement characteristics: 1) reinforced soil deposit to resist and re-distribute seismic shear stresses, 2) increased density and horizontal stress of the surrounding soil, and 3) subsurface gravel drain to enhance dissipation of seismically-induced excess pore water pressure in the soil. Several projects performed in California, in areas of high seismic activity, were tested for the resulting shear reinforcement effects and increased density effects manifested by this method of construction. The stiffness was measured by conducting a load-bearing test immediately on top of an installed RAP. However, no comparisons with unimproved ground were provided. The densification of the site was tested by performing before and after CPT tests on the three sites in California. Two of these sites clearly showed an increased tip resistance to penetration. Tip resistance normalized for clean sands and 1tsf (q_{c1-cs}) was increased to values greater that those suggested in the literature (175). The improvement of these two characteristics should benefit the seismic response of the site and its effectiveness in resisting liquefaction will only be truly tested during an earthquake event.

Paper 4.30a: DEM SIMULATION OF LIQUEFACTION-INDUCED LATERAL SPREADING, by El-Shamy, Zeghal, Dobry, Abdoun, Thevanayagam, and Elgamal. Liquefaction-induced lateral spreading was simulated numerically by using a transient fully-coupled continuum-discrete hydromechanical model. The solid phase was considered as the assemblage of discontinuous particles using DEM, and the pore fluid was idealized using averaged Navier-Stokes equations of conversation of mass and momentum. To solve the problem due to the limited number of particles, which current computers can simulate compared to the actual deposit, a semi-infinite deposit was used by computationally pluviating particles within a parallelepiped domain having periodic boundaries in the two lateral directions. Additionally, the scaling laws were applied to make the analyzed model represent the prototype of the actual deposit, which has a 1°slope. The particle properties were calibrated by modifying them until the shear wave velocity profiles in the DEM matched those in the 1g shake table test done at the University of Buffalo SUNNY. Liquefaction was simulated successfully and excess pore pressure balancing the effective stress occurred at the top of the deposit and progressed downwards. After liquefaction was triggered, the coordination number was less than 4, which is required for a stable assembly. Lateral spreading was found via the time histories of lateral displacement and the shear stress versus strain loops. The permanent shear strain profile showed a transition zone of limited thickness where shear strains are greater than either above or below the depth location of the transition zone, which was also reported by previous researchers. The void redistribution contributed to the appearance of liquefaction in the deposit. The combined action of contraction near the deposit surface and dilation at the deeper locations results in upward pore-fluid flow relative to the solid particle that contributes to the upward drag forces leading to liquefaction.

This paper provides a micro-scale view to understand the mechanism of liquefaction and lateral spreads.

Paper 4.31a: DEM SIMULATION OF LIQUEFACTION-INDUCED LATERAL SPREADING, by El-Shamy and Denissen. The mechanism of liquefaction was explained using a micro-scale characterization of energy dissipation. A transient fully coupled continuum-discrete hydromechanical model was used to simulate saturated deposits of granular particles subjected to seismic excitations. The solid phase was considered as the assemblage of discontinuous particles using DEM, and the pore fluid was idealized using averaged Navier-Stokes equations of conversation of mass and momentum. The input energy and dissipated energy components were monitored during the numerical testing. The appearance of liquefaction was verified at the macro-scale view by examining the time histories of acceleration, excess pore pressure, coordination number, and cyclic shear stresses. At the micro-scale view, the energy is dissipated mainly through inter-particle sliding prior to liquefaction. After liquefaction, however, particle-to-particle imparts damping, which also plays a major role in dissipating energy. This paper is useful to understand the mechanism of liquefaction based on the energy dissipation at the particulate level.

Paper No. 4.33a: LIQUEFACTION COUNTERMEASURE TECHNIQUE BY USING LOGS FOR CARBON STORAGE AGAINST GLOBAL WARMING, by Yoshida, Miyajima, and Numata. The paper presented a technique of ground improvement by installing logs into loose sand layer as a countermeasure against soil liquefaction. Use of logs for ground improvement can enhance the strength of soils and thus reduce the potential of liquefaction. This is an old technique but it seems to be feasible to mitigate the impact of the global warming by using the logs in terms of CO2 storage. A case history is introduced, in which the wood was used as pile foundations near the Kida Bridge in Japan. The visual observation test, the Pylodin penetration test and the compression test were conducted to investigate the soundness of the wood piles retrieved from the riverbed in this case. The results showed that the level of decay of wood piling made of the Japanese cedar which was retrieved from the riverbed was extremely low and they have kept the soundness as the wood pile even though they were buried in the soil under the water level for 59 years. Yoshida et al. (2009) then performed a series of shaking table tests to study the effectiveness of installing logs into ground against liquefaction. The pore water pressure meter, accelerometer, and displacement meter were installed in the shaking table model for monitoring the behavior of soil, pore water, logs (piles), and buildings. Test results clarified that the logs installed in the liquefiable soil layer could increase the resistance of ground against liquefaction and decrease the settlement of structure. As a geotechnical engineer, it may be considerable to increase the utilization of wood in the construction project for contributing to the mitigation of global warming.

Paper No. 4.34a: EFFECTIVE STRESS BASED NUMERICAL ASSESSMENT OF LIQUEFACTION-INDUCED LANDSLIDE AT DEGIRMENDERE CAPE, IZMIT BAY DURING KOCAELI (IZMIT)-TURKEY EARTHQUAKE, by Oral and Çetin. This paper presents a numerical analysis to assess the seismic slope performance at the Degirmendere Cape (Izmit Bay, Turkey), which experienced the strong 1999 Kocaeli earthquake of magnitude 7.4. The study area is located in an active graben system covered by sandy deposits and it is characterized by intense fault activity. The response analysis is performed using a 2D finite difference software. To this purpose, an improved version of the UBCSAND effective stress liquefaction model is implemented. Compared to the original constitutive model, the modified one was proved to be more effective in capturing changes in cyclic pore pressure response of saturated cohesionless soils. Results from the numerical analysis indicate large residual displacements (up to 8m), in agreement with the observed deformations produced by the Kocaeli earthquake. Moreover, high excess pore pressure ratios (> 0.8) were found below a 10m depth, revealing that flow liquefaction was the major cause of instability of the slope under study.

Paper No. 4.36a: SEISMOTECTONIC CONTOURS OF KASHMIR-HAZARA REGION AND SEISMOLOGICAL ASPECTS OF OCTOBER 08, 2005 EARTHQUAKE, by Mahdi. The author provides important contributions in understanding the mechanism of seismic activity of the Kashmir-Hazara region, where the devastating 7.7 moment magnitude earthquake in 2005 was originated. Although the focal depth of this strong earthquake was relatively shallow, approximately 16 km, both the surficial tectonic scars and the deep crustal deformations are discussed in detail. The importance of seismic studies of this zone is emphasized by both the large population exposed to the earthquake hazard (the 2005 event produced more than 100,000 victims) and the potential damage to structures, among them the large Tarbela Dam. It was determined that the Kashmir-Hazara October 8, 2005 earthquake resulted from the subduction of the Indo-Pakistan plate beneath the Eurasian plate and it ruptured the southwest Jhelum Thrust fault, generating the maximum Modified Mercalli Intensity X and the maximum ground acceleration of at least 0.9g (estimated from overturned vehicles near the epicenter). The abnormal number of aftershocks (over 4,000 with magnitude 3 to 5+) suggests that the strong 2005 earthquake imposed increased stresses in adjacent seismic zones, which can result in another major earthquake in the near future.

Paper No. 4.37a: PROBABILISTIC EVALUATION OF FIELD LIQUEFACTION POTENTIAL USING RELATIVE STATE PARAMETER INDEX, by Jafarian, Baziar, Sadeghi, and Vakil. This paper combined both CPT and SPT field test database to perform a probabilistic evaluation of field liquefaction potential by using a relative state parameter index. The relative state parameter index e_R is defined as the void ratio of the soil subtracting the void ration of the soil on critical state line at the same effective stress. This index accounts for both relative density and effective stress, which strongly impact the cyclic stress required for the liquefaction. The study is limited on clean sands and silty sand having up to 15% silts. With using the e_R, both field case histories based on SPT and CPT can be incorporated in the analyses, which allows increased reliability of the probabilistic evaluation of liquefaction potential. Additionally, the paper provided a useful relation between safety factor against liquefaction and liquefaction probability. This may allow the use of probabilistic evaluation of liquefaction potential while the currently used safety factor can be achieved.

Paper No. 4.38a: EVALUATION OF GRAVEL DRAINS EFFECTIVENESS AGAINST LIQUEFACTION IN SHAKING TABLE UTILIZING ENERGY METHOD, by Bahadori and Asadzadeh. The authors have used the energy method to evaluate the effectiveness of gravel drain for dissipating the excess pore water pressure against liquefaction using shaking table tests. The energy method for liquefaction assessment is based on that part of the energy dissipates into the soil during the deformation of the soil under dynamic loading. Compared with the cyclic stress-based and cyclic strain-based approaches, the energy approach is easy to deal with random loading, such as earthquake, because the amount of dissipated energy for liquefaction is independent of loading form. Three types of gravel drain arrangement were evaluated from seven 1-g shaking table tests. Two input motions including a weaker motion with PGA 0.08 g and a stronger motion with PGA 0.15 g were input for each shaking table test. The test results indicate that the gravel drain is an effective approach to against liquefaction. The triangular type arrangement appears to be most efficient for the excess pore pressure dissipation. The efficient of the gravel drain for dissipating the pore water pressure is decreased with stronger input motions. The findings in the paper are valuable for ground improvement and earthquake hazards mitigation. Recommendation for this research is to study which type of gravel drain arrangement is most effective for same area replacement ratio.

Paper No. 4.39a: LIQUEFACTION MITIGATION USING AIR INJECTION, by Camp, Camp, and Andrus. The presence of air bubbles in the soil matrix should reduce the stiffness and pore pressure build-up during dynamic loading. Additionally, the presence of surface tension in the bubbles, if many could contribute to increased resistance in shear. If sufficient de-saturation can be introduced in the saturated soil matrix by means of injecting air or gas into the subsurface, it may result in increased resistance to liquefaction. A series of simple, qualitative shake-table experiments were performed to demonstrate the increase in liquefaction resistance as a result of de-saturation from air injection. Air sparging is a widely used environmental remediation method that involves the continuous injection of air into soil to promote volatilization of contaminants. Although air sparging relies on a continuous flow of gas, Okamura et al. (2006) present data that indicate de-saturation from air injection can last for years or more after an initial, short-term injection period. The experiments showed that intermittent or periodic air injection may be useful in increasing the liquefaction resistance. Other side effects not studied to date are the potential settlement due to the gravity load of the structure due to the static compression of the air bubbles. This idea was originally proposed by others, but the simple tests and continued feasibility studies may render cost effective solutions to mitigate soil liquefaction under structures.

Paper No. 4.41a: FIELD EVIDENCE AND LABORATORY TESTING OF THE CYCLIC VULNERABILITY OF FINE-GRAINED SOILS DURING THE 1999 KOCAELI EARTHQUAKE by Olgun, Martin and Sezen: This paper focused on cyclic vulnerability of plastic fine-grained soils based on a ground failure case history observed at Carrefour Shopping Center construction site after 1999 Kocaeli earthquake. Field extensometers indicated significant settlements, which were associated with undrained cyclic failure of ML, CL and CH type soils. Authors mentioned that existing liquefaction susceptibility criteria could not identify these soils as cyclically-vulnerable (especially CH soils). Considering this deficiency, authors performed field and laboratory tests to understand cyclic response of plastic fine-grained soils better. Test results indicated that even CH type soils can generate significant pore water pressures and exhibit volumetric strains which were not expected according to existing criteria. This paper also highlighted the importance of selected liquefaction definition, i.e. the soil response being referred to define “liquefiable” or “non-liquefiable”. It is concluded that current “non-liquefiable” definition did not mean immunity from pore pressure development and cyclic failure even though there exist a widespread misconception.

Paper No. 4.43a: CASE HISTORIES OF WIDESPREAD LIQUEFACTION AND LATERAL SPREAD INDUCED BY THE 2007 PISCO, PERU EARTHQUAKE by Meneses, Cox, Sancio, Wartman, Alva, Moreno, and Olcese. The M_w 8 Pisco earthquake, which occurred on August 15, 2007 off the Peru coast, caused severe damage to the coastal cities and numerous case histories of liquefaction and lateral spread. The earthquake lasted 200 seconds and included two phases of strong ground motion. Ejection of water and sand up to 1.0 m above the ground surface started during the second phase of the earthquake. Six of the most significant case histories are described in some detail. The furthest liquefaction occurred in a swampy area South of Lima, at some 90 km from the rupture zone; a site with similar geotechnical conditions, North of Lima, at 128 km from the rupture plane, did not show any evidence of liquefaction. Numerous houses were affected by either settlement (up to 0.9 m) or lateral displacement (up to 3.9 m). Slope failures, hundreds of meters long each, occurred in many locations along the coastal highway. A massive liquefaction-induced lateral spread affected a marine terrace approximately 3 km long and 1 km wide. The maximum horizontal displacement was of the order of 25 m. Unfortunately at the present time there are not enough geotechnical data for these case histories to become useful in calibration of liquefaction criteria. The authors assume such data will become available following investigations for reconstruction purposes.

Paper No. 4.45a: PARAMETRIC INVESTIGATION OF LATERAL SPREADING IN FREE-FACE GROUND FORMATIONS, by Valsamis, Bouckovalas, and Dimitriadi. Traditionally, ground surface displacement induced by lateral spreading was evaluated using the empirical correlations. Parameters used in the correlations, such as earthquake magnitude, epicentral distance and peak ground acceleration are assumed to be independent with each other for the lateral spreading evaluation. This paper explores an alternative approach to investigate the lateral spreading displacement using fully coupled and effective stress numerical modeling. The model constants have been calibrated on the basis of data from the laboratory tests performed on the fine Nevada sand at relative densities from 40 to 60 percent and initial effective stresses between 40 and 160 kPa. Then the model was incorporated into the computer code FLAC and was evaluated with 19 previously reported centrifuge experiments with reasonable good agreement. A new correlation was presented though a statistic analysis. The predicted displacements using the new correlation were compared with the field measurements reported by Youd et al. (2002). Although there has been some improvement in the predicted displacements greater than 4 meters, Figure 1 indicates that the accuracy of displacements less than 4 meters remains very difficult to predict. As indicated in their recommendations, better documentation of field measurements combined with better modeling are required before the proposed methodology can benefit the state of the practice.

Paper No. 4.47a: ASSESSMENT OF LIQUEFACTION POTENTIAL RELEVANT TO CHOICE OF TYPE AND DEPTH OF FOUNDATIONS IN SEISMICALLY ACTIVE AREAS, by Hadži-Niković, Perkovic, and Abolmasov. The paper provides a case study of liquefaction evaluation and mediation for a project site located in New Belgrade, Republic of Serbia. The liquefaction potential analysis was performed for the soil up to depth 20 meters. Two approaches were used for the liquefaction evaluation. One used the grain size D_{50} from the laboratory test data. Another used the cone penetration test data from the subsurface investigation. A cost analysis was performed to compare shallow foundation option with ground improvement and deep foundation option. The gravel drain was used to mediate the liquefaction hazard by accelerating the pore water pressure dissipation during the earthquakes. The permeability of the gravel drain was design to be at least 200 times greater than the native soils. The pattern and the spacing of the gravel drain were design on the basis of the work of Seed & Booker (1977). The deep foundation option is to use the deep bored pile foundation penetrating through the liquefiable soils. The cost analysis indicated that the cost of the deep foundation option was more than double of the cost of the shallow foundation with ground improvement.

Paper No. 4.48a: COMPARISON OF THREE APPROACHES FOR EVALUATING EARTHQUAKE-INDUCED SOIL LIQUEFACTION POTENTIAL, by Liao, Meneses, Ortakci, and Zafir. This paper compares the most popular procedures or methods to compute the factor of safety against liquefaction and the post-earthquake reconsolidation settlement. The methods are the Youd et al. (2001) based on the 1998 report by NCEER, which is the one currently used by most engineers or "standard of practice" in the US. Two other new methods, Seed et al. (2003) and Idriss and Boulanger (2008), were compared against the Youd et al. 2001 procedure. Comparisons were presented in graphical from by plotting the ratio of the computed FS of the new methods over the FS computed from Youd et al. (2001). In a similar fashion the post-earthquake deformations were compared, but in this case the new procedures Cetin, et al. (2009) and Idriss and Boulanger (2008), were compared against the Tokimatsu and Seed (1987) methods. For all three analytical frameworks including both SPT-based and CPT-based procedures, it appears that the Idriss and Boulanger (2008) procedures are likely the most conservative, and the Youd et al. (2001) are likely the least conservative. The Seed et al. (2003) procedures are in between regarding the conservatism. The paper also provides some guidelines on how to select the method of analysis depending on the context of the project and the anticipated performance criteria.

Paper No. 4.50a: SOME SEISMOLOGICAL CHARACTERISTICS OF M_W 6.5 PISHIN-ZIARAT OCTOBER 29, 2008 DOUBLE EARTHQUAKE, by Mahdi. The paper investigates in detail the characteristics and effects of the two Pishin-Ziarat (Pakistan) earthquakes, which occurred on October 29, 2008 within an interval of 12 hours of each other. This double event killed approximately 2,000 people and produced extensive damages and economic losses. The author reviews the main seismological characteristics related to this event, such us aftershock pattern, focal mechanism solutions, and ground shaking distribution. The paper starts with a review of the historical seismicity, seismotectonic settings, and geology of the area struck by the Pishin-Ziarat double earthquake. Then, it turns to field investigations and observations, analyzing earthquake-induced effects such as ground cracks, ground failures, and damage patterns. As the main results, the author hypothesizes that this earthquake sequence may be associated to blind strike-slip faults whose activity would be related to the 650-km-long Chaman fault, a major strike-slip source that accommodates a significant amount of the slip across the India-Eurasia plate boundary. The article provides recommendations to mitigate the risks associated with the occurrence of strong earthquake in a region where most buildings and infrastructure are still inadequate to resist strong ground shaking levels.

Paper No. 4.52a: CYCLIC INSTABILITY BEHAVIOR OF SAND-SILT MIXTURE UNDER PARTIAL CYCLIC REVERSAL LOADING, by Baki, Lo and Rahman. A series of cyclic triaxial tests were conducted to investigate the link between static and cyclic instability behavior. The effect of fines content on monotonic and cyclic instability behavior was studied for sand-silt mixtures. Laboratory triaxial tests were used to verify the hypothesis that cyclic instability triggered at nearly identical instability stress ratio as in monotonic test with an initial condition identical to the cyclic tests. The tested sandy soil covered a range of fines content of 0-30%. Based on monotonic tests, the relationship between equivalent granular state parameter (ψ*) and the instability stress ratio (η_{IS}) was obtained and used to compare the instability stress ratio shown in testing under the partial cyclic non-reversal and reversal loading. It was concluded that the hypothesis mentioned before was reasonable and the η_{IS}-ψ* relation obtained from monotonic tests could be used to predict cyclic instability irrespective of fines contents.

Paper No. 4.53a: EQUIVALENT GRANULAR VOID RATIO AND BEHAVIOUR OF LOOSE SAND WITH FINES, by Rahman. The paper presented a very interesting study of using equivalent granular void ratio for liquefaction analysis of sand with fine content. The void ratio is a critical variable for sand behavior under cyclic or seismic loading. When void ratio of sand is greater than the critical void ratio, the sand would perform contractively to increase pore water pressure till liquefaction. Recent research indicates that the void ratio may not be a good parameter for characterizing the behavior of sand with no plastic fines. The critical steady state line was found to be dependent on the fine content. Then equivalent void ratio was presented as an alternative for considering the comprehensive effects of the void ratio and the fine content. Generally, the equivalent void ratio is increased with increase of the fine content since the fine only occupies the space and does not contribute the resistance. However, studies indicate that the fines could participate in the force structure when the fines content reaches certain percentage. Then an empirical parameter *b* was introduced to represents the fraction of fines that are active in force structure. This paper examined many approaches for defining the values of the parameter *b* and compared them using the undrained triaxial data set. It concluded that both “back analysis” and “prediction approach” can provide good correlations. But the prediction approach has the advantage to be used as a prediction tool with simple input. Furthermore, the equivalent granular void ratio was extended to estimate some void ratio related soil properties, such as cyclic resistance to liquefaction and small strain shear modulus.

Paper No. 4.55a: EFFECT OF DENSITY ON CRITICAL DEPTH OF LIQUEFACTION IN A SOIL DEPOSIT CONTAINING DOUBLE LOOSE SAND LENSES, by Hesseini, Pisheh, Nia, and Ganjian. The paper provides a summary of research into the relationship of relative density and critical depth where liquefaction would unlikely happen or the consequential surface deformation would be negligible. The research was performed with numerical simulation using the finite difference computer code FLAC. The sand layers were simulated as called “sand lenses”. Mohr-Coulomb model was used to simulate the behavior of the surrounding cohesive soil. The Finn model in the FLAC was used to represent the stress-strain relationship of the sand lenses. The Finn model has a loosely coupled model to simulate the pore water pressure generation in the sand. Harmonic loading with amplitude of 0.2 g and a frequency of 5 Hz was applied. The relative density of the sand is assumed to be 40%. The results of the analysis are presented as graphs plotting surface displacement versus depth of sand lenses for 5 different strength cases. The authors clearly demonstrate how liquefaction induced displacements become negligible beyond a unique critical depth of the sand lenses, and is directly dependant on soil density. The authors are encouraged to advance the work to the point where some sort of relationship can be expressed in terms of an algebraic expression that will help the reader determine the critical depth at sites with liquefaction potential.

4B: SLOPES, LANDFILLS AND EARTH DAMS

Paper No. 4.01b: BEHAVIOR OF NAILED STEEP SLOPES IN LABORATORY SHAKE TABLE TESTS, by Sengupta and Giri. This paper presents results of laboratory shake table tests performed to study the dynamic behavior of nailed steep slopes. The surface displacements, settlement of the crest and the acceleration responses along with the behavior of the facing wall are examined during the tests. Two 18 cm high 600 and 700steep soil slopes reinforced with nine hollow aluminum nails placed in three rows are considered. Three strain gauges are glued to each nail to measure the tensile force developed in the nails. Four strain gauges are fixed at the center of the facing wall to measure the development of strains during shaking. The acceleration responses at the base and crest of the model slopes are monitored during the tests. The results clearly demonstrate advantage of a nailed slope over unreinforced slope. The failure surfaces observed in the shaking table tests are shallow and of rotational type. The nails oriented in horizontal direction are found to be more efficient. The nail forces and amplification of motion increase with the increase in slope angle and slope height. The amplitude of acceleration toward the outward slope direction is found to be larger than that toward the inward direction in all laboratory shaking tables tests.

Paper No. 4.02b: ASSESSING HORIZONTAL SEISMIC COEFFICIENTS IN EARTH DAMS WITH REGARDS TO EXPECTED DEFORMATION, by Tavakol. This paper attempts to provide a rational basis using a simplified approach for selecting a horizontal seismic coefficient considering the expected permanent displacements as a criterion to evaluate the serviceability levels after an earthquake. The method considers a typical homogenous, infinitely long embankment dam and applies the closed-form solution derived from the shear beam model to assess their horizontal seismic coefficients k_h (Seed and Martin 1966). The computed seismic coefficient time histories are modified to include only the critical (downward) direction of the potential sliding mass and filtered to include only k_h values that have a magnitude larger than 0.05 (bracketed duration). The average value of such time histories is used as the "average seismic coefficient", which is a function of depth from crest. By considering a range of fundamental periods T_1 of the dam, a spectral plot of k_h versus T_1 is developed. Subsequently, the Newmark sliding block method is employed to establish a relationship between assessed horizontal seismic coefficients and expected permanent displacements. For a factor of safety equal to 1, an equation is derived to assess the yield acceleration k_c of a soil wedge, as a function of its height and base width, assuming that the soil resistance develops only at the wedge base. Then, using values obtained from this equation and applying the Newmark sliding block model, probable permanent displacements for various potential sliding wedges for specific earthquake excitations are calculated. The results are presented in a graph of normalized permanent displacements versus the k_c /k_h (Fig. 7). Using this graph and the spectral results of k_h versus T_1 (Fig. 6) an estimation of possible permanent displacements is possible for the considered design earthquake. The methodology could be used as a useful tool for preliminary seismic evaluations of small dams. It is recommended that the methodology is compared with results from existing case histories. The model does not account for the stiffness and possible strength degradation, which may both affect the amount of permanent displacement.

Paper No. 4.03b: ACCURACY OF EMPIRICAL EQUATIONS PREDICTING SLIDING-BLOCK DISPLACEMENT, by Stamatopoulos and Thomaidis. The authors examine the accuracy of existing empirical equations in predicting the sliding-block displacement by using a dataset of 101 accelerograms. The existing empirical equations evaluated in the present study include Ambraseys and Menu (1988), Whitman and Liao (1984), Ambraseys and Srbulov (1993), Sarma (1999), and Yegian et al (1991). The dataset of 101 accelerograms is collected primarily from internet websites and covers a wide range of maximum acceleration, maximum velocity, critical period, average period, earthquake magnitude, earthquake distance, earthquake energy, Arias earthquake intensity. The seismic displacement of the sliding-block model was estimated by the multi-block program developed by Stamatopoulos and presented by Stamatopoulos and Mavromihalis (2009). A block having an inclination of appoximately 10^o was assumed. By varying the frictional strength at the interface between the block and the inclined plane, the cases of critical acceleration coefficient, k_c, 0.03, 0.13 and 0.18 were considered. All accelerograms of the data base collected were applied for each case of k_c. Analysis results show that the Whitman and Liao method is satisfactory for all values of k_c. The Ambraseys and Menu and Yegian methods give satisfactory predictions for k_c=0.03, but not for k_c=0.13 and 0.18. The Ambraseys and Srbulov and Sarma methods do not give satisfactory predictions for either k_c=0.03, 0.13 or 0.18. In addition, the seismic displacement is related better with the maximum velocity and maximum acceleration than to other factors of the applied accelerogram such as the dominant period, the earthquake magnitude and the earthquake distance.

Paper No. 4.04b: THE EFFECT OF THE GEOMETRY CHANGES ON SLIDING-BLOCK PREDICTIONS, by Stamatopoulos and Mavromihalis. The authors note that the Newmark-type sliding-block approach for seismic slope stability analyses does not consider the change in geometry of the sliding mass towards a stable configuration. In this paper a methodology for correction of the displacements predicted by the sliding-block method to account for changes in geometry is proposed. The development of the empirical equation for correcting the sliding-block method results was based on a previously developed procedure named "multi-block model" and calibrated on a simplified two-block (wedge) model. The sliding surfaces under both the multi-block or under the wedge are not kinematically possible, so movement is not possible without blocks deformation, which is not in agreement with the basic assumption of the Newmark approach of a rigid, non-deformable block. Additionally, in the traditional Newmark-type analyses the movement stops immediately after the occurrence of the last loading cycle that exceeds the yield level, not when the deformed shape reaches the stable shape. Therefore, it is not appropriate to consider the proposed methodology a correction to the sliding-block results, but has the potential of being developed in an independent procedure for evaluation of displacements in slopes.

Paper No. 4.05b: NUMERICAL ANALYSIS OF FAILURE OF RUDRAMATHA DAM SECTION DURING 26TH JANUARY, 2001 BHUJ EARTHQUAKE, by Babu and Srivastava. This paper describes an investigation of a coupled nonlinear dynamic numerical analysis (using commercially available finite difference code FLAC 5.0) of the failed Rudramata dam section during the Bhuj earthquake. Results are discussed to understand the mechanism and underlying causes of failure of the dam. The Finn-Byrne model is used in the numerical analysis to take into consideration the important aspects of dynamic loading i.e. pore pressure generation. The analysis is performed using the acceleration time history record of the Bhuj earthquake developed by Iyengar and Raghukanth (2006) involving analytical procedures. Characteristics of 26th January 2001 Bhuj Earthquake and tectonic features of Kachchh region are described in detail. The study concludes that presence of a liquefiable layer beneath the earthen dam foundation was the major cause of either failure or for the significant damage within the body of the dam cross-section.

Paper No 4.08b: NONLINEAR TIME-DOMAIN ANALYSIS OF A SLIDING BLOCK ON A PLANE, by Arab. This paper examines numerically the widely used method of a sliding rigid block on a plane with an elastic-perfectly plastic interface using the commercial finite difference code FLAC. The model is very simple and consists of two rows of material elements with an interface, which are placed either horizontal plane or on an inclined plane. The model was developed in an attempt to model the seismic behavior of geosynthetically-lined landfills. The numerical model seems capable of predicting accurately the slip-stick and slip-slip behavior obtained from an analytical solution by Westermo and Udwadia (1983) for behavior of a sliding block on a horizontal plane. Westermo and Udwadia presented an analytical solution for a rigid mass resting on a flat horizontal surface with an interface friction coefficient, μ, excited with a simple harmonic motion of amplitude a_o. They showed that the system experienced two different slippage conditions that were independent of the frequency of the harmonic motion and depended only on a non-dimensional parameter $\eta = \mu g/a_o$. The quantity μg is the yield acceleration at which the block begins to slide relative to the plane. The effect of η on the response of a rigid block on a horizontal plane with a slip-stick response and with a slip-slip response based on the numerical model is shown in a plot. The numerical model is also used to predict the shaking table tests of a sliding block on a horizontal plane conducted by Kavazanjian et al. (1991) to demonstrate the ability of a layered geosynthetic system to provide frictional base isolation. In these tests, a rigid block with one geosynthetic material glued to its bottom side was placed on a shaking table that had also an attached geosynthetic material. Moreover, the model was used to predict the results of shaking table experiments by Elgamal et al. (1990) of a block on a plane inclined at 10°. Finally, it was used to simulate the experimental behavior of a rigid block on a shaking table test with an inclined plane, having a high-density polyethylene interface similar to those in a geosynthetic liner used in landfills (Wartman 1999, and Wartman et al. 2003). Although similar numerical model have been used previously by other researchers (some of them using finite difference and others using finite elements) for the evaluation of permanent displacements in embankment dams, retaining walls, etc, the comparison with several experimental results and analytical solutions presented in the article offer a useful insight into the subject of permanent seismic deformation.

Paper No. 4.10b: GEOTECHNICAL CHARACTERISTICS OF THE SEISMICALLY-INDUCED ARATOZAWA LANDSLIDE, JAPAN, by Gratchev and Towhata. This paper presents the results of a geotechnical investigation of seismically-induced Aratozawa landslide in Japan, located in the vicinity of the Aratozawa Dam. This landslide was clearly the largest failure caused by the Iwate-Miyagi Nairiku earthquake, which struck the Tohoku region, northeastern Honshu, Japan on June 14, 2008. The landslide extended about 1.2 kilometers long and 800 meters wide. The total volume of the sliding body was estimated to be 67 million m3. The height of a newly created cliff was about 150 meters, making this landslide one of the largest failures that occurred in the past few decades in Japan. A research group from the University of Tokyo, including the writers, conducted a field survey to evaluate the in-situ properties of soil involved in sliding and collected the data necessary to understand the mechanism of slide initiation and development. The survey showed that the shape of the landslide was significantly affected by displacements of the original ground surface, resulting in a complex system of ridges and depressions. The ridges were formed from relatively hard volcanic rocks while the depressions were mostly filled with fine-grained material.
A series of laboratory cyclic loading triaxial compression tests were also conducted to investigate the dynamic properties of undisturbed and reconstituted samples. Laboratory data indicated that a loss of strength could occur in the volcanic soil as the result of pore-water pressure build-up. From the results obtained in this study and the data presented by other researchers, the mechanism of the Aratozawa slope failure can be hypothesized as follows: in the early stages of the earthquake, a weakened zone and slip plane developed in the volcanic rocks due to high pore-water pressures induced by the shaking and the subsequent loss of strength. Once failure occurred in the volcanic material, sliding of the landslide mass was initiated along the already existing slip plane in the siltstone, resulting in extensive lateral movements.

Paper No. 4.12b: COMPARISON OF LIQUEFACTION TRIGGERING ANALYSIS APPROACHES FOR AN EMBANKMENT DAM AND FOUNDATION, by Serafini and Perlea. The paper compares various approaches for liquefaction triggering analysis on the Success Dam located on the Tule River, near the city of Porterville, California. The dam is a rolled earth-fill embankment approximately 145 feet high and 3,400 feet long. The embankment is comprised of a central impervious core protected by upstream and downstream outer pervious zones. Due to a majority of the dam is founded on potentially liquefiable Holocene alluvium, further liquefaction evaluation is essentially required. They described thoroughly the existing embankment design and materials, foundation conditions, field investigations and material properties, and site seismicity. In this study, the following analytical techniques were used on the Success Dam Remediation Project: (1) cyclic stress ratio (CSR) evaluation using peak shear stresses obtained from QUAD4M equivalent linear seismic response type analyses, (2) evaluation of QUAD4M element shear stress time histories using a cycle counting approach to approximate the potential excess pore water pressure ratios, and (3) more advanced non-linear dynamic FLAC analyses using UBCSAND to evaluate excess pore water pressure ratios for potentially liquefiable materials. For the last item, the earthquake simulation and post-earthquake analysis using the finite difference program FLAC incorporated with the UBCSAND model, which was originally developed at the University of British Columbia, Canada (Byrne et al., 2004) were performed. The liquefaction evaluation using relatively simplified QUAD4M analyses was also conducted and the results were further compared with those of the FLAC seismic deformation analysis. Comparisons made between the three methods demonstrated some of the advantages and limitations in utilizing each approach. In general, the simplified methods and the more advanced FLAC-UBCSAND yielded the same end result under the MCE and OBE loading. Verification of FLAC results, in terms of acceleration amplification, induced cyclic stress and excess pore pressure can be successfully accomplished using the program QUAD4M coupled with the simplified procedure for liquefaction. However, in some cases the extent of predicted liquefied zones can be underestimated using the QUAD4M and coupled with the simplified liquefaction procedure approach due to the nature of the equivalent linear approach and the inability to account for pore pressure migration. In these cases, the UBCSAND model appears to better estimate excess pore water pressure generation and liquefaction potential.

Paper No. 4.13b, STABILITY ANALYSIS OF FLOOD PROTECTION EMBANKMENTS AND RIVERBANK PROTECTION WORKS, by Goswami R. K. and Singh B.: This paper presents a feasibility study aimed to reduce the risk of flooding due to riverbank erosion of the Brahmaputra river in the Assam state (India). In this region, flooding is mainly related to the geomorphologic evolution of the Himalayan Mountain Building, tectonic processes, and to monsoon rainfall. In addition, large earthquakes can cause landslides and rock falls that may influence the normal fluvial regime. Earthquake activity is also responsible for liquefaction in the floodplains, leading to failure of riverbanks and embankments. The study describes a stability analysis to estimate the factor of safety of flood embankments under static and dynamic conditions. Static slope stability analysis is performed for three embankment sections using different approaches: simplified Bishop method, simplified Jambu method, and Morgenstern and Price method. Results obtained from the application of these three approaches are similar, with safety factors greater than 1.4. Dynamic analyses are also performed using a procedure similar to the conventional Newmark's method. The authors find maximum permanent deformations of around 15.6mm. Finally, the paper discusses works for riverbank protection (e.g., construction of revetments, use of sand-filled geobags).

Paper No. 4.15b: SEISMIC ANALYSIS OF THE RESERVOIR-EARTH DAM-PORE FLUID SYSTEM USING AN INTEGRATED NUMERICAL APPROACH, by Han and Hart. The analysis of an earth dam subjected to seismic loading using the finite-difference program FLAC is presented in this paper. The major requirements of a dynamic behavior numerical simulation are described in a template format, so the proposed model can be easily applied to practical problems, changing the material properties. The example is a homogeneous clay embankment on a liquefiable sand layer above the bedrock. The main steps of modeling, described in some detail by the authors, include: design of grid resolution for correct seismic wave propagation; deconvolution of the design time history for application at the base of the model; fluid-mechanical and cyclic shear-volume couplings (the built-in FLAC Finn-Byrne model for excess pore pressure generation is used); hysteretic damping and shear modulus degradation modeling. A relatively new feature of the FLAC program is the automatic remeshing algorithm, which replaces the badly distorted mesh with a new regular mesh whenever needed during the problem solving. It is not specified if re-meshing was needed in the example provided, where the maximum displacements were of approximately 7.5 feet. Generally, FLAC runs in large strain mode accept displacements of many tens of feet without need of remeshing; an alternate method of dealing with distorted meshes is to use a function that stops the run before the distortion becomes unacceptable and to correct manually the mesh before continuing the run. This alternate procedure has the advantage of being applicable when the embankment and/or foundation include more than one material, which is generally the case of actual structures.

Paper No. 4.16b: SEISMIC PERFORMANCE EVALUATION OF A SUBMARINE GAS PIPELINE, by Roth, Crouse, Dawson, Su, and Hefer. The paper examines the seismic performance of a proposed offshore gas flowline, which connects a manifold in 830-m water depth to a riser platform in shallow waters of the outer continental shelf, approximately 200 km off the mainland in Western Australia. The flowline is placed on a 10° continental slope. The seafloor is composed of deep carbonate sediments of sands and silty clay. The fundamental question investigated by the paper is the potential for liquefaction and significant permanent displacements that may affect the pipeline safety. To this end, soil properties were derived from PCPT and T-bar data, bender element tests, and monotonic and cyclic direct simple shear tests. The study presents results from two types of analyses for a critical segment of the pipeline, where it traverses a narrow ridge between two deep submarine canyons: (1) probabilistic analyses using simplified empirical methods; and (2) deterministic 2D and 3D analyses with FLAC using a nonlinear, effective-stress soil model fully coupled with an empirical pore-pressure generation scheme by Dawson et al. (2001). The 3D numerical model is shown in Fig. 2a. The results show that a critical segment of the pipeline is seismically stable. Probabilistic analyses indicated that the likelihood of liquefaction or large shaking induced deformations along this segment of the pipeline is extremely small with return periods of 10,000 years. Maximum pore-pressure ratios in the soils underlying the pipeline area were computed to be $\approx 50\%$ in the 2D model and $\approx 30\%$ in the 3D model. Permanent ground displacements were computed with deterministic 2D and 3D FLAC analyses for a 5,000-year event and resulted to be very small. The article offers an interesting case study of seismic evaluation of a submarine pipeline that is based on good experimental data and extensive analytical investigation.

Paper No. 4.17b, STABILITY ASSESSMENT AND SUGGESTION FOR CONTROL MEASURES OF A POTENTIAL LANDSLIDE SLOPE ON NH 94, UTTARAKHAND HIMALAYA, INDIA by Ghosh, Sarkar, Kanungo, Chauhan and Ahmad: This paper describes an investigation of a potential unstable slope where habitation and land resources are under risk situated at Agrakhal along Rishikesh – Uttarkashi highway (NH 94) to evaluate the magnitude of instability and to suggest possible control measures. The slope has many houses, which have shown distress due to landslide activity. The study also involved geological and geotechnical investigations, slope stability analysis and monitoring of movements. Slope instability in the area is manifested by road subsidence and continuous development of cracks in the houses situated on the slope. The paper also highlights the field observations and results of the study.

Paper No. 4.19b: THE STABILITY AND DEFORMATION LIMIT STATE CORRESPONDING TO THE HIGH ROAD EMBANKMENTS CLOSE TO A BRIDGE, by Chirica, Vintila, and Tenea. The paper described a case study that the numerical analysis was conducted to study the stability and deformation corresponding to high road embankments close to a bridge with variable height (between 4-10m) at Iassy, Romania. The analysis contains the following models: 1) Model with the soils in natural state; 2) Model with foundation soil in flooded state, 3) Model with foundation soil in flooded state and different artificial consolidation on embankment width. Before the performance of such numerical analysis, a series of tests in open system (CK0D) and tests in closed system (CK0D-A) were conducted for determining part of soil parameters, which are used in the numerical analysis. Specifically, the PLAXIS software was used for the first two modeling and the Geo-slope software was used for the last modeling of dynamic analysis according to the Romanian seismic code P100-2006. The analysis results may be of interest to the engineer when dealing with similar engineering cases.

Paper No. 4.22b, DESIGN OF AN EXTERNAL WASTE ROCK DUMP IN AN OPENCAST COAL MINE STANDING AGAINST A HILL IN SEISMIC PRONE AREA OF INDIA, by Roy. The author investigates the seismic slope stability of a waste rock dump standing against a moderately sloped hill in India; where the opposite side constitutes the site of the quarry operations in an opencast coal mine. Back analysis of the present state of the dump having a height of 80 m is used to calculate the stability of the maximum planned height of 180 m. The overall safe slope is proposed as 24 degrees with respect to the horizontal. Remedial measures such as installing Garland drains at the toe and placing Gabion walls are considered to be useful against possible failure.

Paper No. 4.23b: INCORPORATION OF THE SPATIAL CORRELATION OF ARIAS INTENSITY WITHIN EARTHQUAKE LOSS ESTIMATION, by Foulser-Piggott and Stafford. The paper presents a very interesting study whose purpose is the development of a model for spatial correlation of Arias intensity values at multiple locations. The paper firstly describes the development of a new empirical relationship for the prediction of Arias intensity. The model is calibrated based on recordings previously used for the development of the NGA ground motion predictive equations. The functional form adopted by the authors expresses the Arias intensity as a function of common predictors (i.e., magnitude, distance, style-of-faulting), terms to account for nonlinear site response, and the average shear-wave velocity over the upper 30m. The introduction of this latter variable represents a significant enhancement of the new model over existing relationships, which are used to adopt dummy variables for site classes. The Arias intensity predictive model is then used to derive the spatial correlation model, which is presented in the second part of the article. This latter model is developed through construction of empirical semi-variograms for the intra-event residuals of two well known seismic events, the Chi-Chi and Northridge earthquakes. The paper concludes proposing a schematic but useful representation of a method via which the spatial distribution of Arias intensity may be incorporated within a loss estimation model that includes landslide effects.

Paper 4.24b: SEISMIC STABILITY ASSESSMENT THE RAISING OF THE GEITA TAILINGS STORAGE FACILITY, TANZANIA, by Theron, Wagener, and Steenkamp. This case study contributes to industry knowledge by laying out a process by which various construction methods for tailings dam expansions (upstream or downstream raises) can be evaluated for potential liquefaction. The existing state of the tailings (prior to dam expansion) were evaluated using methods based on procedures of Fear and Robertson (1995) and Been and Jefferies (1985). Results were in good agreement, with both predicting a very contractive deposit. The case history also provides an informative summary of the laboratory test data and ground motion parameters required for both a dynamic finite element analysis (using QuakeW) and subsequent pseudo-static limit equilibrium analysis. Stability results are presented for the different design options along with discussion of other issues affecting design choices; namely issues regarding material volumetrics/economy and environmental constraints. Results indicate that upstream raises can be realized in seismically active areas if proper drainage is considered between the tailings and dam shell material. Downstream dam raises represent the safest option considering seismic stability, but excessively large footprint area and necessary construction materials negatively affect this design option.

Paper No. 4.25b: NUMERICAL MODELLING OF EARTHQUAKE-INDUCED ROCK LANDSLIDES: THE 1783 SCILLA CASE-HISTORY (SOUTHERN ITALY) by Bozzano, Esposito, Martino, Montagna, Paciello, Porfido, and Lenti. Dynamic numerical modeling by the finite-difference FLAC 6.0 program was performed to back-calculate a rock landslide that was triggered by a series of strong earthquakes in 1783 in Southern Italy. The huge landslide with an estimated volume of 5 million cubic meters produced a tsunami wave responsible for more than 1,500 victims on a nearby beach. For the numerical modeling a 400 x 200 zones mesh with 5 m squares was used; the authors considered the mesh resolution compatible with the applied seismic motion characteristics. An elastic perfectly plastic constitutive law (Mohr-Coulomb model) was attributed to all zones of the model; after static gravitational equilibrium was reached, the sequence of earthquakes was applied as horizontal acceleration time history along the base of the mesh; during the dynamic stage, where plasticity state was reached the dynamic shear modulus was reduced down to the measured value in the landslide debris by in situ down hole investigations. The results of the modeling were in good agreement with the available information based on old documents and current field condition. They confirmed a post-seismic trigger of the rock-avalanche related to the second main shock of the 1783 seismic sequence and the final geometry was in good agreement with the present evidence of the landslide scar area. What is probably the most important, additional analyses showed that future earthquake generated landslides are not probable with the current shape of the slope.

Paper 4.26b: ISSUES IN THE USE OF EMPIRICAL CORRELATIONS FOR ESTIMATING THE RESIDUAL UNDRAINED SHEAR STRENGTH OF LIQUEFIED SOILS, by Gillette. This paper provides a critical review of the empirical relationships developed and utilized for the estimation of post-liquefaction residual strengths from standard penetration test data. All the analyzed relationships are empirically based correlations developed from documented case histories. Currently, the relationships display a significant amount of scatter due to the small amount of documented case histories, uncertainty in material properties, different adjustments for fines contents, and the potential for different mechanisms to govern strength during straining (such as void redistribution and formation of water films). The author discusses the inclusion and/or exclusion of certain case histories during the development of each relationship, and the available case histories were evaluated for completeness considering a range of penetration data and overburden stresses. The current catalog was found to be deficient for alluvial foundation deposits with blowcounts in the low to middle teens. The differences in drainage properties between natural alluvial foundation deposits and the engineered dam materials are discussed and related to the greater quantity of documented failures in the generally less permeable dam materials. The recent trend to normalize the residual strength by the effective overburden stress (prior to failure) and the basis and impacts of this normalization process are discussed. Finally, the author presents (2) new statistical relationships fitted to the data of Seed and Harder (1990) and Stark and Olson (2002).

Paper No. 4.28b: 2D FEM ANALYSIS OF EARTH AND ROCKFILL DAMS UNDER SEISMIC CONDITION, by Basudhar, Rao, Bhookya, and Dey. The paper pertains to the seismic analysis of earth and rockfill dams with the aid of MSC-Nastran (Windows) package. After validation, the package has been used to investigate the dynamic response of Tehri Dam, located in the seismically active region of Himalayas. A 2D FEM analysis is adopted wherein the dam has been modeled as a linear, elastic, non-homogeneous material. The base acceleration data of the Bhuj Earthquake has been used as an input motion. Effect of Poisson's ratio and the ratio of the canyon length to the height of the dam has been investigated and is reported. Acceleration-time histories reveal that the maximum acceleration occurs at the crest of the dam, and decreases towards the bottom of the dam. Displacement-time histories reveal that the vertical displacement at any locations of the dam is negligibly small compared to the horizontal displacement. The shear stresses evaluated display a maximum and minimum magnitude at the shell and core of the dam respectively. Velocity-time history results shows a maximum velocity in the forward direction at the crest of the dam, while in the reverse direction, the same is experienced by the shell and the core of the dam supplemented by a noticeable phase difference.

Paper No. 4.29b: EFFECT OF CANYON GEOMETRY AND GROUND CONDITIONS ON THE SEISMIC PERFORMANCE OF TENDAHO EARTHFILL DAM IN ETHIOPIA, by Berhe and Wu. Investigated the effect of canyon geometry and ground conditions on the seismic performance of the Tendaho earthfill dam in Ethiopia. The effect of canyon geometry on the deformation characteristics of earthfill dams caused by the seismic loading can be referred to the arching effect. Such effect cannot be properly considered when a 2D plane strain numerical analysis is employed. As a result, they incorporated a 3D finite difference modeling FLAC3D into the dynamic numerical analysis on the Tendaho earthfill dam. In the analysis, the behaviors of the geomaterials are described by an elastic-plastic Mohr-Coulomb constitutive model. This is so because the elasto-plastic analysis constitutes an efficient tool for the investigation of stability of dams under seismic loading. The numerical model outlined above has been applied to four different cases of canyon geometry in terms of the slope of the triangle valley. The dynamic analysis is carried out for the horizontal El Centro earthquake scaled to different acceleration magnitudes, 0.15g, 0.3g and 0.6g. The results of analyses for the different shapes of the valley assumed revealed that the canyon effect diminishes with decrease in the slope of the valley below about 270, two dimensional analyses can suffice for dams with are constructed on valley with slope less than about 270. But if the slope angle is greater than about 27°, 3D analysis has to be carried out. The plane strain analysis (2D) gives conservative results as compared to real 3D analysis. If plane strain analysis (2D) is carried out for dam to be constructed in valley with slope angle greater than about 27°, then the analysis will be on the safe side. In the case where carrying out 3D model analysis is expensive then a 2D model analysis with reduction factor that takes the arching or canyon effect into account can be done. In addition, the liquefaction potential of alluvium soil layers and the amplification value of the peak ground accelerations for the dam are also evaluated. Those results could contribute to the design of earthfill dams, which are constructed on a valley.

Paper No. 4.30b: CENTRIFUGE MODEL TESTS OF TIEBACK ANCHORS AND DRAINAGE PIPES FOR STABILIZATION OF SLOPES UNDER EARTHQUAKE LOADS, by Ota, Takeya, Itoh, and Kuraoka. The paper presents very interesting results from three centrifuge tests on the seismic behavior of tieback anchors and drainage pipes used for stabilization of slopes. It shows common types of construction measures taken to increase slope stability in real applications. In this study the centrifuge tests that are used to investigate the performance of tieback-reinforced slopes include models (1) without groundwater (2) with groundwater and (3) with groundwater and drainage pipes. The centrifuge models tests have demonstrated very clearly that the presence of groundwater substantially increased the amount of slope displacement due to increased high excess pore water pressure during shaking. Moreover they showed that drainage pipes are a very effective means of controlling excess pore water pressure, slope displacements, and axial forces on the tieback anchors. It was concluded that in real applications the use of drainage pipes in such slopes may reduce the overall construction cost.

Paper No. 4.31b: A PROBABILISTIC METHOD FOR THE PREDICTION OF EARTHQUAKE-INDUCED SLOPE DISPLACEMENTS, by Barani, Pelli, and Bazzurro. This paper presents a proposed probabilistic method for estimating earthquake induces slope displacements as a function of one or more ground motion parameters. For establishing the correlation relationships, a finite difference mesh modeling an infinite slope was evaluated with the program FLAC 5.0. Twenty time histories, applied as cyclic normal and shear stresses at the base of the mesh, covered a large variability of earthquake motion: moment magnitude between 3.9 and 6.9, epicentral distance of 3.7 km to 107 km, and peak horizontal ground acceleration between 0.03g and 0.54g. Good correlations were found between the residual displacement and either Housner intensity or Arias intensity. The authors also compared the results obtained with FLAC and with either the conventional Newmark's rigid-block method or with a decoupled approach. The standard Newmark's method severely underestimated the residual displacement; the decoupled displacements were within about 20% of the coupled results obtained with FLAC. The authors consider that the proposed method, which used as an example a landslide occurred in Central Italy, can be applied to any kind of slope, including embankments and earth/rockfill dams. When coupled with Probabilistic Seismic Hazard Analysis at the slope site, it can provide estimates of the annual probability that a permanent deformation of the slope will be exceeded.

Paper No. 4.32b, SEISMIC STABILITY OF THE NAILED SLOPES, by Waseem and Pratibh: The study focuses on assessing the performance of nail reinforced slopes under various patterns of superimposed strip loading, using the pseudo-dynamic approach. Soil friction angle, embedment ratio, horizontal and vertical seismic accelerations are chosen as the variables used in the parametric study. Using the upper bound limit analysis, the values obtained from the study are compared with the available results reported by pseudo-static method of analysis. Based on the values of critical acceleration to be used in sliding block analyses, application of reinforcement is found to be impractical at high values of seismic coefficient.

Paper No. 4.37b: STATIC AND DYNAMIC BEHAVIOR OF EARTHEN SLOPES IN THE REGION OF UTTARKASHI, INDIA, by Bhat, Saxena, and Prasad. The paper is mainly a brief summary of some classic methods of analysis for the static slope stability, seismic slope stability, and finite element seismic analysis of slopes. The paper includes a brief example using the code QUAKE/W for the dynamic analysis and SLOPE/W for Newmark type permanent displacement analysis. The article does not offer any improvement of the methods of analysis or a carefully investigated case study.

Paper No. 4.39b: AN EMPIRICAL PREDICTIVE RELATIONSHIP FOR ASSESSING THE SEISMIC STABILITY OF SLOPES by Lee, Green, and Finch. The objective of this study is to develop an empirical predictive relationship for permanent relative displacements for use in assessing the seismic stability of slopes, dams, and/or embankments subjected to active shallow crustal earthquake motions at rock sites. A total of 330 horizontal motions, recorded at rock sites during 29 earthquakes in active shallow crustal regions (e.g., western North America: WNA), were selected. Newmark sliding block method was used to compute the permanent relative displacements for a suite of yield-accelerations: 0.01, 0.05, 0.10, and 0.20 g. The displacement data were then correlated to the maximum ground acceleration (Amax) and velocity (V_{max}). The predictive relationships proposed in this study were developed by performing separate regressions for each k_y using the non-linear mixed-effects (NLME) technique. Performing separate regressions for each k_y allowed the relationships to have relatively low standard deviations and to have simple functional forms that are independent of k_y. The resulting relationships have simple functional forms and graphical representations are well prepared.

Paper No. 4.40b: EFFECT OF A SLOPE ON THE DYNAMIC PROPERTIES OF DILUVIAL TERRACE, by Nakai, Nagata, and Sekiguchi: The paper presents an interesting study aimed to examine the effects of a slope on the seismic response of a diluvial terrace based on ground investigations (microtremor measurements), ground motion observations, and 2-dimensional dynamic analyses. The Chiba city (east of Tokio) is selected as target area. Results from microtremor measurements point out that, at sites located in the valley plain near the slope, the fundamental frequency decreases in accordance with the distance from the foot of the slope. Conversely, at sites located near the edge of the terrace, the predominant frequencies tend to increase with increasing the distance from the shoulder of the slope. Results from seismic motion observations reveal that the largest accelerations tend to be concentrated at the edge of the terrace where they can be as large as twice those observed in the valley plain or in the middle of the terrace itself. Spectral ratios of seismic recordings agree with those derived from microtremor measurements. Regarding numerical simulations, firstly the authors discuss the effects of the height and inclination of a slope characterized by a uniform soil on the site response. The effect of the ground stiffness is also kept into account. They conclude that the ground response is mainly influenced by the height of the slope and the soil stiffness. The effect of the slope angle is small or negligible. The authors also examine the effect of weakened soils along the slope, observing that maximum accelerations tend to concentrate close to the slope shoulder. Moreover, they observe that the influence of weakened soils on ground response is larger than that of slope geometry. Finally, the paper presents a 2-dimensional elasto-plastic finite element analysis to assess the effect of a weakened soil on the failure risk during earthquakes. This analysis confirms the previous observations indicating, moreover, that the ground acceleration is dependent on the frequency content of input waves. Furthermore, the presence of weakened soil is found to have a strong influence on the strain distribution along the slope but no or little effect on maximum velocity.

Paper No. 4.41b: SEISMIC SLOPE STABILITY OF REACTIVATED LANDSLIDES – A PERFORMANCE BASED ANALYSIS, by Tiwari and Hillman. The paper provides valuable insight related to how the water table and earthquake acceleration impact safety factor for the slope stability under earthquake loading. Eight different methods were considered for comparison, which includes Ordinary, Bishop Simplified, Janbu Simplified, Janbu Corrected, Spencer, Army Corp #1, Army Corp #2 and Morgenstern-Price. It is not clear the difference for the difference between Army Corp #1 and #2. Case history 2005 Bluebird Canyon Landslide was used for soil profile. A sensitivity analysis was performed varying 15 different water table elevations and 10 different seismic loadings. The results indicated that the Army Corp #2 method always gave the least conservative results and the Ordinary method gave the most conservative results. Not all methods could give the converged results for all water and seismic conditions. When the seismic coefficient is greater than 0.5, only the Army Corp #2 and Ordinary methods provided converged results. However, having the seismic coefficient greater than 0.5 is not common. Army Corps of Engineers manual for seismic design of new dams requires use of a seismic coefficient of 0.1 in Seismic Zone 3 and 0.15 in Seismic Zone 4, in conjunction with a minimum factor of safety of 1.0. The analysis results also indicated that the safety factor was generally increased with lowering the water table with exception for the Army Corp #2 method. Although the paper provides valuable results related to the various slope stability methodologies, it would have been better if a firm conclusion on which methodology worked best for the case history.

Paper 4.43b: USING RECORDED EARTHQUAKE SIGNALS FOR DYNAMIC ANALYSIS OF MASJED SOLEIMAN EMBANKMENT DAM by Sakhi, Davoodi, and Jafari. The Masjed Soleiman Dam, with a maximum height of 177 m, is the highest rockfill dam in Iran and is well equipped with accelerometers on the crest, mid-height of slope, and at the base, in the gallery under the middle core. Using recorded earthquake motion in the gallery for excitation of a numerical model, the computed motions at mid-height of slope and the crest, were compared with the actual records at these locations. Earthquake records (particularly of the January 6, 2004 earthquake that triggered all accelerographs), explosions, ambient and forced vibration tests were used to evaluate the dynamic characteristics of the dam materials. The numerical modeling used a 2-D mesh with 2381 elements and 4996 nodes and the computer program PLAXIS. To determine the best way to model the dam-foundation interaction, different assumptions were considered with respect to foundation rigidity and the assumption that led to the best fit of computed movements with recorded data was selected for the evaluation of the dynamic parameters of the dam materials.

Paper No. 4.44b: IMPROVED METHODOLOGY FOR ESTIMATING SEISMIC COEFFICIENTS FOR THE PSEUDO-STATIC STABILITY ANALYSIS OF EARTH DAMS, by Papadimitriou, Andrianopoulos, Bouckovalas, and Anastasopoulos. This paper proposes a new simplified methodology for estimating seismic coefficients for the pseudo-static stability analysis of earth dams, based on statistical analysis of results from 28 two-dimensional seismic analyses on eight earth dams. They illustrate the definition of important parameters of the problem of seismic response and stability analysis of earth dams and tall embankments. The methodology estimates the seismic coefficients k_h as function of: a) the maximum acceleration of the free-field surface of the foundation soil b) the predominant period T_e of the seismic excitation, c) the first natural period T_o of the dam, d) the dam foundation stiffness and e) the depth of the failure surface normalized over the height of the dam. More specifically, in step (1) the peak acceleration of the free-field surface of the foundation soil and the predominant period of the seismic excitation T_e are estimated through an equivalent linear (shake-type) analysis; the PGA may be also estimated through approximate correlations based on parametric numerical studies. In step (2) the first natural period of the dam T_o is computed based on existing expressions (from shear-beam type models) and reduced to account for the degradation of stiffness with the magnitude of seismic shear strain. In step (3) the maximum crest acceleration $a_{max,crest}$ is estimated as function of the natural period T_o, the predominant period T_e of the excitation and the relative stiffness of the foundation soil. In step (4) the value of the maximum seismic coefficient k_h for a given depth of the potential failure surface is estimated. Finally, in step (5) the effective seismic coefficient k_{he} is computed as a fraction of k_h (e.g. $k_{he} = 0.67k_h$). The methodology has a standard deviation of the relative error equal to ±24% compared to numerical results and can be used as a practical tool in preliminary seismic evaluations of dam pseudo-static stability. However, there are still certain issues that need to be better understood to improve the accuracy of the method. These include: (a) the effects of both the soil nonlinearity in the dam body and the relative stiffness of the dam/foundation soil, affecting the computation of $a_{max,crest}$; (b) the effect of the failure surface (i.e. its maximum depth and perhaps its maximum thickness); (c) the effects of the presence of the reservoir water; and (d) the effects of the 3D canyon geometry.

Paper No. 4.46b: 3D ANALYSIS OF THE SEISMIC RESPONSE OF SEVEN OAKS DAM, by Mejia and Dawson. The paper presents a well-documented case study for a site response analysis of the Seven Oaks Dam located in San Bernardino County, California. The dam is an earth dam with structural height of about 640 feet, crest length of 2,760 feet, and a volume of 38 million cubic yards. The dam site was instrumented with six accelerometers at different depth. In addition, two accelerometers were located about 0.5 km downstream to represent the free field. Since the crest length to height ratio is less than 6, the 3-D behavior may have a pronounced effect on the site response of the dam. A 3-dimensional model was created in the FLAC3D. The recorded rock outcrop time histories from the 2001 Big Bear Lake earthquake and the 2005 Yucaipa earthquake were used as the input motions. The response analysis results indicate that the dam material exhibited significant nonlinear behavior even for the moderate intensity of shaking. With appropriately determined material reduction and damping curves, the calculated motions agreed well with the recorded motions. For comparison, the site response analysis was also performed for a 2-D model. The good agreement between the 3-D and 2-D analyses indicates that the 3-D behavior does not play a significant role as anticipated.

Paper No. 4.47b: SEISMIC BEHAVIOR OF ASPHALTIC CONCRETE CORE DAMS, by Ghanbari, Mojezi, and Fadaee. The article attempts to investigate the seismic behavior of asphaltic concrete-core dams. It considers a 75 m high rockfill dam, having a 1 m thick asphaltic core and two 4.5 m thick filters. The authors do not refer to the material nonlinear constitutive models used for the rockfill, filter and asphaltic materials, although the given properties imply the use of a Mohr-Coulomb model for both the static and dynamic analyses. Moreover, they do not provide any information (or any publication reference) on the finite difference code used (referred to as "CA2"). The analysis uses a factor of safety against large crest settlements defined by the ratio of PGA to cause a crest settlement of 1 m over the PGA of the actual design earthquake. As the paper does not take into account the dynamic properties and cyclic behavior of the dam materials, and does not explain the method of analysis, its findings are of limited value to practicing engineers.

Paper No. 4.48b: ASSESSMENT OF SOIL-NAILED EXCAVATIONS SEISMIC FAILURE UNDER CYCLIC LOADING AND PSEUDO-STATIC FORCES, by Panah and Majidian. In this paper two numerical analysis methods (cyclic time history and pseudo-static) are applied to simulate the seismic behavior and failure mechanism of soil-nailed structures. The numerical simulations are performed using a finite difference software approach, such as FLAC. Nevada sand soil parameters are used and construction sequences of nailed-structures are simulated prior to the cyclic and pseudo-static analyses. The results revealed that the failure pattern of the two kinds of analyses is approximately similar and comprised of bilinear sliding surfaces. Furthermore, good agreement is found between failure pattern of two types of numerical analyses and previous experimental tests based on the comparison between facing displacements in two considered analysis methods. A simple process is presented to achieve the seismic coefficient consistent with the peak ground acceleration. Presentation of considered method is based on supposition that failure occurs at the constant pullout displacement of bottom-row nails for both analysis methods.

Paper No. 4.51b: DYNAMIC SLOPE STABILITY ANALYSIS BY A RELIABILITY-BASED APPROACH, by Abdel Massih, Soubra, Rouainia, and Harb. This paper by presents a reliability-based approach for the seismic slope analysis. The random variables considered are the cohesion and the shear modulus of the soil. The stochastic response surface methodology (SRSM) is used for the evaluation of the probability distribution of the horizontal permanent displacement at the toe of the slope. The deterministic numerical model used in the reliability analysis is based on the finite difference code FLAC3D. An example plot is presented for the computed density function of the permanent horizontal displacement at the toe slope. The reliability analysis is developed on a well-established and rather elaborate methodology. However, the deterministic seismic analysis suffers from the use of the Mohr-Coulomb constitutive model, which is inappropriate for dynamic analysis of soil systems. The use of inappropriate stiffness and damping during seismic analysis casts serious doubt on the results and conclusions of the work presented.

Paper No. 4.52b: THE EFFECTS OF CANYON TOPOGRAPHY ON DISTRIBUTION PATTERN OF DYNAMIC STRESSES IN EARTH DAMS, by Ghanbari, Mojezi, and Fadaee. The paper compares 2D and 3D stability analyses performed for modified Alborz earth dam (Iran) geometries in an attempt to quantify the local effects of three-dimensional topography. Ten scenarios were investigated in which the valley geometry (rectangular or triangular) and the shape factor (dam L/H ratios) were fluctuated. Additional analyses were performed for a theoretical quarter-section to compare the valley geometry effects away from the maximum cross-section. Analyses were performed using FLAC2D & FLAC3D software and a Ricker wave pulse input motion. Conclusions were drawn using the shear stress ratio (τ_{xy2D}/τ_{xz3D}). Maximum shear stresses for the 3D analyses were found in the x-z plane as compared to the other axes, and thus the 2D and 3D analyses used dynamic shear stresses in x-y plane and in the x-z plane, respectively. In general, results showed that 2D analyses predict slightly higher dynamic shear stresses as compared to 3D analyses. The results indicated that as the shape ratio increases the shear stress ratio decreases for both triangular and rectangular valley geometries, but never reaches unity for the given shape ratios, thus topographic effects increase for narrower valleys. Quarter-section analyses showed larger stress ratios compared to the maximum-section results, thus topographic effects intensify closer to the valley walls. The authors conclude that available 2D techniques used to predict the response of dams built in narrow valleys are not adequate, and 3D analyses should be performed. This paper provides further evidence that the local effects from valley topography are a reality and sometimes quite significant for certain geometries and cross-sections. The authors have quantified the effects in this study for the given soil properties and chosen valley and dam geometries. While comparisons are often made using crest accelerations, it would have been beneficial to see this data.

Paper No. 4.53b, EARTHQUAKE INDUCED SLOPE FAILURE SIMULATION BY SPH by Bui, Fukagawa, Sako, and Okamura. This paper describes an investigation of smoothed particle hydrodynamics (SPH) method in conjunction with an elasto-plastic (Drucker-Prager) stress-strain model, which has been shown to be a reliable and robust method for post-failure behavior simulation of a slope subject to earthquake loading. As the standard numerical tool, the finite element method (FEM) is employed to analyze majority of slope stability, slope displacement and soil liquefaction problems subjected to earthquake loading condition. However, mechanism of soil failure in such condition often involved extremely large deformation and failure behaviors, which were unable to be modeled by FEM since this method was suffered from the grid distortion. In an attempt to overcome this limitation, the numerical framework (SPH method) was applied to simulate the failure behavior of a slope subjected to a seismic loading. The effect of pore-water pressure was assumed negligible for the sake of simplicity. The proposed SPH method has been validated by comparison of the numerical result with data measured during suitable experiments. It is shown that SPH can simulate fairly well the slope failure behavior in the model test, especially in prediction of the failure surface. The authors are encouraged by these results but recognize the need for further improvement of the numerical method. Advantage of the method is its robustness, conceptual simplicity, relative ease of incorporating new physics, and especially its potential to handle large deformation and post-failure behaviors. As a result, the paper suggests that SPH should be considered as a powerful alternative for computation of geomaterials subjected to earthquake loading conditions.

PAPER NO 4.57b, CYCLIC TORSIONAL SHEAR TESTS TO OBTAIN DYNAMIC SOIL PROPERTIES FOR SEISMIC DESIGN OF ROAD EMBANKMENTS, by Yasuda and Tsuruda: This paper describes seismically-induced damages on road embankments. Authors performed cyclic torsional shear tests on partially and fully saturated specimens from sites, where deformations were observed after 2004 Niiegataken-chuetsu and 2007 Notohanto earthquakes, to study cyclic strength, shear modulus and excess pore water pressure characteristics of embankment soils. They concluded that: i) cyclic strength and shear modulus of partially saturated soils are greater than those of saturated soils, ii) variation in plasticity index affects the cyclic strength, shear modulus and excess pore water pressure ratio of both partially and full saturated soils, and iii) increasing factor of safety against liquefaction leads to a decrease in residual pore water pressure ratio. It is a valuable effort considering the importance of earthquake-induced damages on road embankments, even though authors' conclusions are rather trivial. This paper would have been more interesting, if authors had increased the depth of their discussion on application of experimental results on seismic design procedures since it was their primary goal. Moreover, an illustrative example would serve well considering the authors' intentions on developing a performance based design approach.

Paper No 4.58b: THE EFFECT OF EARTHQUAKE RECORD SCALING TECHNIQUE ON EMBANKMENT DAM RESPONSE, by Karimian, Wightman, Sriskandakumar and Yan. The paper investigates the effect of three different types of earthquake excitation scaling for seismic analysis of dams. It compares the response (a) using linear scaling of the selected records to the target spectral acceleration at the significant period; (b) matching the uniform hazard response spectrum (UHRS); and (c) developing the conditional mean response spectrum of a ground motion (CMS-ε) given a target value of the spectral acceleration for the significant period range based on Baker and Cornell (2005, 2006a, 2006b). In CMS-ε, the shape of the spectrum is dependent on the number of standard deviations needed for a ground motion prediction equation to return the target value of spectral acceleration. The response spectrum by CMS-ε falls below that by the UHRS at periods other than the significant period range and is more appropriate for design. Comparisons of the response spectra are made between the horizontal and vertical UHRS and CMS-ε. The three methods are compared in the safety assessment of one of BC Hydro's embankment dams. The seismic analysis of the dam was conducted using the program FLAC, the nonlinear hysteretic soil stress-strain relationship and the Mohr-Coulomb failure criterion. In this model the variation of the modulus and damping with strain matches the shape of standard curves based on laboratory tests. The paper shows that the results of the CMS-ε analysis yield 20% smaller response values compared to the more conservative UHRS method. The results of horizontal and vertical permanent displacement at the crest for the three methods and the three excitations are presented in tabular form. A second important conclusion of the study is that the inclusion of the vertical component increases the crest settlement by 75-85%. The paper demonstrates that the use of the CMS-ε method may lead to a more economical design and therefore this option should be considered in the seismic evaluation of new and existing dams.

Paper No. 4.61b: FINITE ELEMENT MODELING OF THE LAS COLINAS LANDSLIDE UNDER EARTHQUAKE SHAKING, by Vu Khoa and Jostad. The Las Colinas Landslide, which took place in El Salvador, Central America, was subjected to earthquake shaking in a finite element model. Hill's sufficient condition of stability was explained with the presentation of local and global second-order work criteria. They were implementation into the finite element code

PLAXIS. The soil behaviors in Las Colinas slope was modeled using the non-associated Hardening soil model. By analyzing the cones of potentially unstable stress directions and the boundary of the unstable domain of the specific case of the paleo-soil material, it was shown that the large domains of potentially material instabilities described by the local second-order work criterion can appear strictly inside the Mohr-Coulomb failure surface. Based on the stability analysis of the Las Colinas slope, it was verified that the ability of FE model to employ local and global second-order work criteria to exhibit the main landslide zones in-situ. By compacting the safety factors calculated with the methods of slices and shear strength reduction technique, the global second-order was more pertinent indicator for predicating the global stability of the Las Colinas slope.

Paper No. 4.63b, EVALUATION OF SEISMIC RESPONSE OF EXTERNAL MINE OVERBURDEN DUMPS, by Koner R. and Chakravarty D.: In this paper the seismic response of overburden dumps is investigated with the aim of providing useful information to reduce georisks in mining areas. The paper starts with a brief review of previous scientific studies dealing with problems related to admissible permanent slope displacements for design consideration. Subsequently, the paper presents a summary of slope stability analysis methods, from static approaches to more complex dynamic methods. Finally, a 2-dimensional nonlinear finite difference analysis is performed to analyze the role played by different soil and ground motion parameters on the seismic response of a dump. Conclusions point out that permanent displacements (and deformations) increase with dump height and slope gradient. Moreover, it is observed that the dump response varies as a function of the seismic motion characteristics. Finally, the authors observe that cracks can develop due to tension zones at the top of the dump.

Paper No. 4.65b: LANDSLIDE HAZARD MAPPING AND ASSESSMENT IN HIMALAYAS, by Pachauri. This paper is a brief description of an attempt to develop a method for landslide hazard mapping and assessment, which is applied in the Himalayas. According to the paper, the method classifies the terrain on the basis of slope steepness and takes into account factors like distance from seismic fault, rock type, density, drainage, fracture density, relief, and geotechnical data. The work has a long-term approach to landslides, with objective the identification of slopes vulnerable to slides. It would be useful to present a more detailed quantitative description of the methodology and how the aforementioned factors are taken into account in the assessment of landslide hazard. In its present descriptive form, the usefulness of the article is limited.

Paper No. 4.66b: REPAIR OF LANDSLIDE UMKA-DUBOKO - SEISMIC PERFORMANCE ASSESSMENT, by Sesov and Zugic. The paper presents the seismic performance assessment for the Umka-Duboko landslide near Belgrade (Serbia). This large active landslide develops in marly-clay soils and extends over an area of approximately 1.8km^2. Liquefaction and slope stability analyses are performed in order to define potential risks for motorway embankments crossing the landslide. Following a description of data available from field investigations and laboratory tests, the paper presents results obtained for the most critical slope profile. The analyses are performed assuming a linear behavior of soils, consistent with the low seismicity level of the study area, and for different water levels and values of residual shear strength. Two reference earthquakes, representative of different hazard levels, are used as input in the dynamic analyses. For a seismic action corresponding to a mean return period of 475 years, the factor of safety ranges from approximately 1.25 to 1.6 while Newmark's displacements are up to 79cm. The analysis is then repeated using a Monte Carlo approach to allow for the uncertainty in the residual shear strength only, which was found to be the most uncertain geotechnical parameter. As a final result, a probabilistic estimation of residual displacements is given by applying a simplified method based on the Poisson occurrence model.

FINAL REMARKS AND TOPICS FOR DISCUSSION

This session 4 on liquefaction and slope instabilities and deformations continues to be the most popular in this series of conferences. Participation and contributions of many countries were received on important topics in geotechnical earthquake engineering. The papers reflect a high level of technical expertise among the international geotechnical engineering community and the increased participation of less developed countries, where resources may be limited. Considering that we still do not have long lasting solutions to the many problems in geotechnical earthquake engineering, we need to continue fostering creativity and optimization of resources in the engineering community to yield improvements in this field. Some articles consisted on the application of well-established methodologies in geotechnical earthquake engineering in places where this practice has been remiss, the co-reporters consider these advances in the field. The engineering research community continues to be reminded that research findings need to be converted to design and codes to avoid situations such as, the recent disturbing events in Haiti in the aftermath of the January 12, 2010 earthquake.

TOPICS FOR DISCUSSION

The purpose of the discussion topics below is to establish a communication venue between the authors and the delegates of this Conference to foster what we expect to be a lively and vigorous dialogue.

- Discretization issues of computational domains: FEM, FDD, and DEM.
- Generalization of the energy approach in liquefaction related applications
- The reliability of in-situ tests for the assessment of liquefaction potential
- The effect of non-plastic fines on the susceptibility of granular soils to liquefaction.

- Soil nailing as an efficient remediation technique for slopes subjected to seismic loading.
- Most innovative mitigation techniques can they be effective?

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REFERENCES

Ambraseys N. and Srbulov M. [1995]. "Earthquake induced displacements of slopes," Soil Dynamics and Earthquake Engineering; 14, pp. 59-71.

Andrus, R.D., Stokoe, K.H., II. [2000]. "*Liquefaction resistance of soils from shear-wave velocity*," *Journal of Geotechnical and Geoenvironmental Engrg.,* ASCE, 126(11), 015-1025.

Baker, J.W. and C.A. Cornell [2005]. "*A Vector-Valued Ground Motion Intensity Measure Consisting of Spectral Acceleration and Epsilon*". Earthquake Engineering and Structural Dynamics, April 2005, Vol. 34, No. 10, pp. 1193-1217.

Baker, J.W. and C.A. Cornell [2006a]. "*Correlation of Response Spectral Values for Multicomponent Ground Motions*". Bulletin of the Seismological Society of America, February 2006, Vol. 96, No. 1, pp. 215-227.

Baker, J.W. and C.A. Cornell [2006]. "*Spectral Shape, Epsilon and Record Selection*". *Earthquake Engineering and Structural Dynamics*, April 2006, Vol. 35, No. 9, pp. 1077-1095.

Been, K. and Jefferies, M. G. [1985] "A state parameter for sands", *Geotechnique* Vol. 35, No. 2, pp 365 - 381.

Bilge, H.T., and Cetin, K.O [2008]. "Probabilistic assessment of cyclic soil straining in fine-grained soils". Proc. of Geotech. Earthquake Engnrg. and Soil Dynamics IV, GSP 181, Sacramento, CA, USA.

Byrne, P.M., Roy, D., Campanella, R.G., and Hughes, J. [1995]. "Predicting Liquefaction Response of Granular Soils from Pressuremeter Tests", *ASCE National Convention, ASCE, GSP 56,* pp. 122-135.

Byrne, P.M., Park, S.S., Beaty, M., Sharp, M.K., Gonzalez, L., and Abdoun, T. [2004]. "Numerical modeling of liquefaction and comparison with centrifuge tests," Canadian Geotechnical Journal, V ol. 41(2):193-211.

Cetin K.O., Bilge H.T., Wu J., Kammerer A. and Seed R.B., [2009]. "Probabilistic Models for Cyclic Straining of Saturated Clean Sands." J. Geotech. and Geoenv. Engrg., 135[3], 371-386.

Dawson, E.M., W.H. Roth, S. Nesarajah, G. Bureau, and C.A. Davis [2001], "A practice oriented pore-pressure generation model", Proceedings, 2nd Int. FLAC Symposium, Lyon France, October.

Elgamal, A.-W. M., Scott, R. F., Succarieh, M. F., and Yan, L. [1990]. "La Villita Dam response during five earthquakes including permanent deformation", *J. of Geotech. Engrg.,* ASCE, 116(10), 1443-1462.

Fear C. E. and Robertson P. K. [1995]. "Estimating the undrained strength of sand: A theoretical framework." Canadian Geotechnical Journal, Vol. 32, No. 4, pp 859 – 870.

Grasso, S., M. Maugeri, [2006]. "Using KD and Vs from seismic dilatometer (SDMT) for evaluating soil liquefaction". *Proc. Second Intern. Flat Dilat. Conf.*, pp. 281-288.

Idriss, I.M., and R.W. Boulanger [2008], "*Soil Liquefaction During Earthquakes*". Earthquake Engineering Research Institute, MNO-12, Oakland, California.

Iyengar, R.N., Raghu Kanth, S.T.G. [2006]. "Strong Ground Motion Estimation during the Kachchh, India Earthquake", Pure and Applied Geophysics, Vol. 163, pp. 153-173.

Kavazanjian, E., Jr., Hushmand, B., and Martin, G.R. [1991]. Frictional Base Isolation Using a Layered Soil-Synthetic Liner System", Proc., 3rd U.S. Conference on Lifeline Earthquake Engineering, ASCE Technical Council on Lifeline Earthquake Engineering Monograph No. 4, 1139-1151.

Monaco, P., S. Marchetti, G. Totani, M. Calabrese, [2005]. "Sand liquefiability assessment by Flat Dilatometer Test". *Proc. 16th Intern. Conf. Soil Mech. and Geo. Engrn.,* Osaka, pp. 2693- 2697.

Okamura, M., K. Ishiharaand K. Tamura [2006]. "Degree of saturation and liquefaction resistance of sand improved with sand compaction pile," *Journal of Geotechnical and Geoenvironmental Engineering*, 132(2), pp. 258-264.

Olson, S.M. and T.D. Stark [2002], "Liquefied Strength Ratio from Liquefaction Flow Case Histories," *Canadian Geotechnical Journal*, v. 39, 629-647.

Papathanassiou G., S., Pavlides B., Christaras and K., Pitilakis [2005]. "Liquefaction case histories and empirical relations of earthquake magnitude versus distance from the broader Aegean Region". *Journal of Geodynamics*, No 40, pp. 257-278.

Papathanasiou, G., S. Pavlides, S. Valkaniotis and A. Chatzipetros, [2009]. “Towards the compilation of a liquefaction susceptibility map of Greece”. *SRL*, Vol. 80, No. 2, pp. 316.

Reyna, F. and J.L. Chameau, [1991]. “Dilatometer based liquefaction potential of sites in the Imperial Valley”, *Proc. 2nd International Conference on Recent Advance in Geotechnical Earthquake Engineering and Soil Dynamics 3.13, St. Louis, Missouri* (1991), pp. 385–392.

Sarma, S. K. [1999]. "Seismic slope stability - The critical acceleration", Proceedings of the Second International Conference on Earthquake Geotechnical Engineering, Balkema, Lisbon, 1999, pp. 1077-1082.

Seed, H. B. and Booker, J. R. [1977]. “Stabilization of Potentially Liquefiable Sand Deposits using Gravel Drains”, *ASCE J.,Geotech. Engg. Division,* V. 103 (7), pp.757– 768.

Seed, R. B., K.O. Cetin, R. E. S. Moss, A.M. Kammerer, J. Wu, J.M. Pestana, M.F. Riemer, R.B. Sancio, J.D. Bray, R.E. Kayen, and A, Faris [2003]. “Recent Advances in Soil Liquefaction Engineering: a Unified and Consistent Framework*”,* Keynote presentation, 26th Annual ASCE Los Angeles Geotechnical Spring Seminar, Long Beach, CA.

Seed R.B. and Harder Jr., L.F. [1990]. “*SPT-based Analysis of Cyclic Pore Pressure Generation and Undrained Residual Strength*”: Proc., H.B.Seed Memorial Symp., Vol. 2, BiTech Publishing, Vancouver, B. C., Canada, 351-376

Seed H. B., and Idriss I. M. [1971], "*Simplified Procedure for Evaluating Soil liquefaction Potential*," *J. Soil Mechanics and Foundations Div*., SCE, 97:SM9, 1249-1273.

Seed, H. B., and Martin, G. R. [1966]. “The Seismic Coefficient of Earth Dam Design”. *Journal of the Soil Mecha. and Found. Div.*, ASCE, Vol. 90, No. SM6, pp. 25-58.

Stamatopoulos C. and Mavromihalis C. [2010]. “The Effect of the Geometry Changes on Sliding-Block Predictions.” Fifth International Conference on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics and Symposium in honor of professor I. M. Idriss.

Tokimatsu, K., and H.B. Seed [1987]. “Evaluation of Settlements in Sands Due to Earthquake Shaking”, ASCE Journal of Geotechnical Engineering, 113(GT8), 861–78.

Tsai, P. H., D.H. Lee, G.T.C. Kung, and C.H. Juang, [2009]. “Simplified DMT-based methods for evaluating liquefaction resistance of soils.” *Engineering Geology*, Vol. 103, No. 1-2.

Unutmaz, B. [2008]. “Assessment of soil – structure – earthquake interaction induced soil liquefaction triggering.” PhD Dissertation, Middle East Technical University, Ankara. pp. 13-22.

Wartman, J. [1999]. "Physical model studies of seismically induced deformation in slopes", PhD Dissertation, Univ. of California, Berkeley, Calif.

Wartman, J., Bray, J.D., and Seed, R.B. [2003]. “Inclined plane studies of the Newmark sliding block procedure”,. J. Geotech. Geoenviron. Engrg., ASCE, 129(8): 673–684.

Westermo, B. and Udwadia, F. [1983]. “Periodic response of a sliding oscillator system to harmonic excitation”, Earthquake Engrg. Struct. Dyn. 11, 135-146.

Whitman, R. V. and Liao S. [1985]. Seismic design of retaining walls. Miscellaneous paper GL-85-1, US Army Engineer Waterways Experimental Station, Vicksburg, Mississippi.

Yegian M. D., Marciano E. and Ghahraman V. G. [1991]. Earthquake-inced permanent deformations: probabilistic approach. Journal of Earthquake Engineering, ASCE, vol. 117, no 1, pp 35-50.

Yoshida, M., Numata, A., Motoyama, H., Kubo, H., Miyajima, M. and Nomura, T. [2009]. “*Shaking Table Tests on Countermeasure against Soil Liquefaction by Using Japanese Cedar Logs*”, Proc. of the 64th Annual Meeting of Japan Society of Civil Engineers, pp.533-534 (in Japanese).

Youd, T. L., I.M. Idriss, R.D. Andrus, I. Arango, G. Castro, J.T. Christian, R. Dobry, W.D. Liam Finn, L.F. Jr. Harder, M.E. Hynes, K. Ishihara, J.P. Koester, S.S.C. Laio, W.F. Marcuson III, G.R. Martin, J.K. Mitchell, Y. Moriwaki, M.S. Power, P.K. Robertson, R.B. Seed, K.H. Stokoe II [2001]. ‘‘Liquefaction Resistance of Soils: Summary report from the 1996 NCEER and 1998 NCEER/NSF workshops on evaluation of liquefaction resistance of soils’’, ASCE *Journal of Geotechnical and Geoenvironmental Engineering*, 127(10): 817–833.

Youd L. T., Hansen M. C. and Bartlett F. S. [2002]. "Revised multilinear regression equations for prediction of lateral spread displacement", *Journal of Geotechnical and Geoenvironmental Engineering*, Vol. 128, No. 12, December 1, pp 1007-1017.