General Report — Session 7

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GENERAL REPORT ON SESSION 7

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INTRODUCTION

This General Report presents a summary of the 16 papers accepted for Session 7. The session is divided into Session 7a (seismic analysis and retrofit of foundations of bridges and other sub-structures, seismic retrofit projects and procedures in California), Session 7b (case histories of geotechnical earthquake engineering, failures and geotechnical analysis of recent earthquakes), and Session 7c (geotechnical earthquake engineering issues in San Diego Region).

The papers originate from nine countries and cover important issues in the field of geotechnical earthquake engineering and the San Diego Region. Table 1 presents a list of the papers ordered by breakout sessions. The summaries below intend to provide a general overview of the focus of the papers and intend to orient the reader to areas of interest. The Session 7 organizers greatly appreciate the efforts of the authors and commend the quality of the accepted papers.

Table 1 – List of Papers for Session 7

Paper No.	Origin	Authors	Breakout Session
7.02a	Iran	F. Rahimzadeh Rofooei and M.R. Malek Mohammad.	
7.04a	United Kingdom	S.C. Darren Chian and S.P. Gopal Madabhushi	
7.05a	USA	Te-Chih Ke, Hubert Law, and Po Lam	7a
7.06a	Mexico	Juan M. Mayoral and Francisco A. Flores	
7.10a	Russia	C.A. Dzhantimirov, V.A. Barvashov, S.A. Rytov, and P.V. Smirnov	
7.01b	USA	A. Sadrekarimi and T. Starke	
7.04b	Iran	H. Niroumand	
7.12b	Greece	D. Manou, M. Manakou, M. Alexoudi, A. Anastasiadis, and K. Pitilakis	7b
7.14b	Canada	H. Plewes, B. Chambers, T. Jibiki, A. Sy, and R. Friedel	
7.01c	USA	L. Handfelt, I. Wong, P. Thomas, T. Dawson, and J. Zhou	
7.02c	USA	J. Gingery, S. Rugg, and T. Rockwell	
7.03c	USA	L. Shao and J. Kinley	7c
7.04c	USA	S. Weedon and G. Cannon	
7.05c	USA	S. Arora, R. Stroop, and L. Shao	
7.06c	USA	T. Rockwell	
7.08c	India	B. Pal and M. Panda	

Session 7a – Seismic Analysis and Retrofit of Foundations of Bridges and Other Sub-Structures, Seismic Retrofit Projects and Procedures in California

Paper No. 7.02a, THE INFLUENCE OF IRREGULARITY ON THE VALUES OF DEMAND MODIFIER FACTOR IN ASCE 41-06, by *F. Rahimzadeh Rofooei and M.R. Malek Mohammad*. This paper presents a study on the factors recommended by ASCE 41-06 focusing on several symmetrical and asymmetrical concrete moment resisting frame structures. The demand modifier factor values are studied under nonlinear dynamic and scaled nonlinear dynamic analyses.

Paper No. 7.04a, FLOATATION OF TUNNEL IN LIQUEFIABLE SOIL, by *S.C. Darren Chian and S.P. Gopal Madabhushi*. This paper investigates the floatation of tunnels in liquefiable sand deposits through centrifuge model testing,. Tunnels generally have a lower unit weight than the surrounding soil. When submerged in saturated soil, the developing buoyancy force is counter-balanced by the weight and shear strength of the overlying soil, prohibiting floatation. However, during strong seismic shaking the soil may liquefy and loss most of its shear strength. If the effective buoyant force is greater than the overlying soil weight, the tunnel may move upwards : floatation. Centrifuge models were prepared at relative density $D_R \approx 45\%$. Tunnels of diameter D were buried at depth $H = 1.1D$ and $1.5D$ to investigate the effect of depth on floatation response. The sand was saturated with high viscous methyl cellulose fluid, which is adequate to simulate water in the centrifuge. A recently developed saturation system (CAM-Sat, Stringer & Madabhushi, 2009) was used, running with a programmable software platform called DASYLAB, and relying on real-time monitoring of the fluid flow rate (derived from the change in weight) to adjust the optimum pressure difference between the feeding tank and the model box. The results of the tests confirm the susceptibility of buried structures, such as tunnels, to floatation in case of seismic liquefaction. It is shown that floatation takes place only during strong seismic shaking. Its initiation is found to be influenced by the sudden application of cyclic loading. The tunnel depth is shown to play a key role : a shallow tunnel is more vulnerable to floatation given the lower weight of the overlying soil.

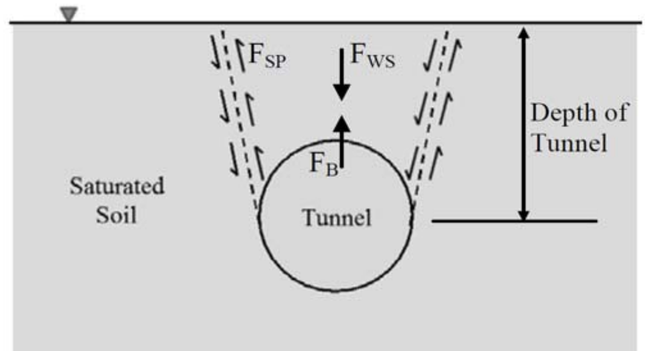

Fig. 1. Force components acting on tunnel under static conditions.

Paper No. 7.05a, GROUND MOTION STUDY ON DUMBARTON TOLL BRIDGE, by *Te-Chih Ke, Hubert Law, and Po Lam*. This paper presents the key findings of a probabilistic study conducted for the Seismic Retrofit of a Toll bridge connecting Newark with East Palo Alto in the San Francisco Bay Area (California). An idealized soil profile was developed, based on extensive on-land and over-water field investigation. Following the results of probabilistic and deterministic seismic hazard analyses incorporated with new seismic source model and Next Generation Attenuation (NGA) models, a 1,000-year return period spectrum was adopted for the Safety Evaluation Earthquake (SEE) event and a 100-year return period spectrum for the Function Evaluation Earthquake (FEE) event. Site response (applying the equivalent linear method, code SHAKE) and kinematic soil-pile interaction (utilizing code KIPS) analyses were conducted to develop pier-specific kinematic time histories. The results of the study were compared with deterministic spectra. Uniform hazard spectra were developed for the reference rock motion at six return periods: 100-, 300-, 475-, 1,000-, 1,500-, and 2,000-years. Seven sets of spectrum-compatible rock motion time histories were developed for each of the SEE and FEE events. These time histories were used to conduct the aforementioned free-field site response and kinematic soil-pile interaction analyses at selected piers. Time histories of kinematic motion and depth-varying free-field motions were developed at all piers for nonlinear time history analysis of the bridge.

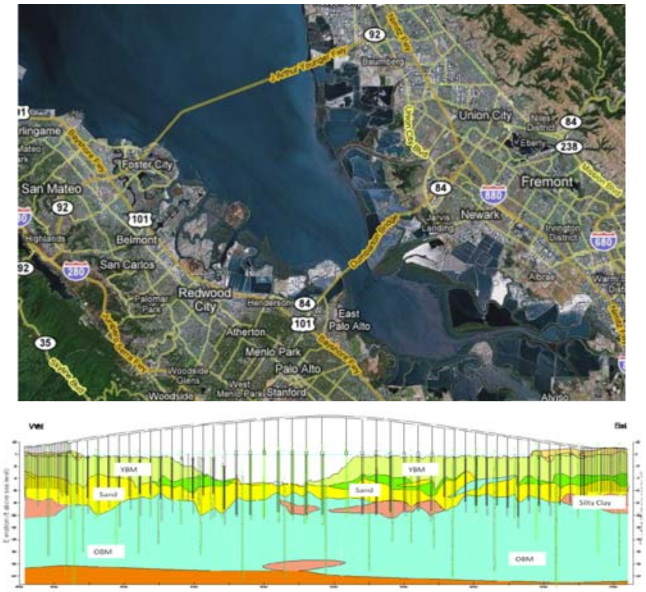

Fig. 2. Dumbarton Bridge plan view (top), and longitudinal section along with idealized soil profile (bottom).

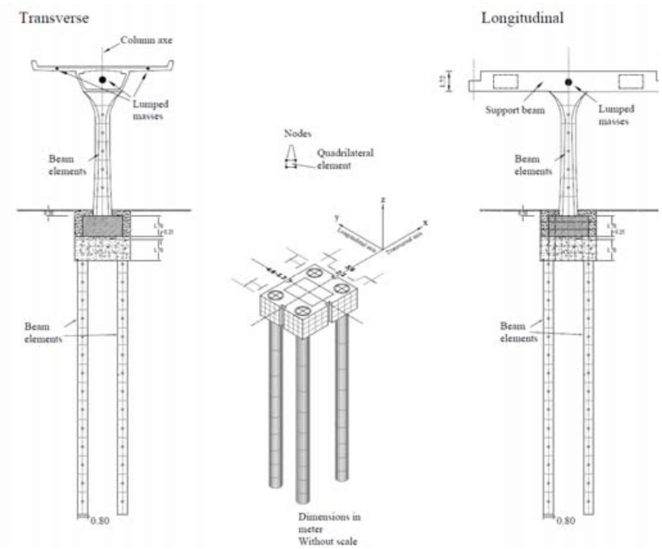

Fig. 3. Finite element model of the analyzed critical support of the Urban overpass in Mexico city.

Paper No. 7.06, NUMERICAL STUDY OF THE SEISMIC RESPONSE OF AN URBAN BRIDGE SUPPORT SYSTEM, by *Juan M. Mayoral and Francisco A. Flores*. This paper analyzes the seismic performance of one of the supports of a 23 km strategic urban overpass, which is to be built in the transition and hill zones of Mexico City. The deck of the bridge is monolithically connected to piers, founded on 2 x 2 piled foundations. Subsoil conditions typically consist of soft to stiff clay and medium to dense sand deposits, randomly interbedded by loose sand lenses, and underlain by rock formations that may outcrop in some areas. The specific support that was analyzed consists of a 8.4 m tall pier, founded on 2 x 2 cast-in-place d = 0.8 m piles, with a 3.6 m x 4.6 m pilecap. The analyses were conducted applying the finite element method, utilizing the numerical code SASSI. The soil profile was modeled with equivalent linear properties to account for soil non-linearities. The foundation was represented with two-dimensional quadrilateral elements with equivalent volumetric weight and stiffness. The modeling methodology was validated through analysis of the seismic response, during the 1999 M_w 7 Tehuacan earthquake, of another instrumented bridge support, also located within the surroundings of Mexico City, but at the lake zone, where highly compressible clays are found. Then, the validated finite element model was used to analyze the seismic response of the critical support of the urban overpass. The performance was evaluated for the design earthquake in terms of transfer functions and displacement time histories.

Paper No. 7.10a, APPLICATION OF HIGH-POWER ELECTRICAL SPARKS FOR DYNAMIC COMPACTION OF SOIL, by *C.A. Dzhantimirov, V.A. Barvashov, S.A. Rytov, and P.V. Smirnov*. This paper describes an electrical discharge technology, applied for deep soil compaction around a borehole. Based on dynamic compaction by pulsed electric spark, this technology can be useful to increase the bearing capacity of piles, micropiles, soil anchors and nails in low-density saturated sands. The method is based on the emission of short-duration electric pulses, generated with several-second intervals, which produce shock waves within the soil, followed by vapor and gas cavity action, thus applying hydro-dynamic pressures on borehole walls. Laboratory experiments and in-situ field tests were conducted to investigate the effectiveness of the method. Since electrical spark in soil is a practically non-observable event, the laboratory experiments were conducted in water to allow for qualitative observations. It was found that longer pulse efficiency is higher and can be increased by addition of special admixtures. Full-size bored piles, micropiles, and soil anchors were tested in-situ at construction sites. It is shown that pile (anchor, or nail) bearing capacity may be increased by 50% to 100% through electrical spark treatment. However, when applied to strengthen existing footings sitting on cohesionless soils prone to dynamic softening, special care should be taken to reduce the risk of additional softening of soil under the building that could lead to additional settlements. In such cases, the electric discharge technology is recommended outside the active zone of the footing to be underpinned.

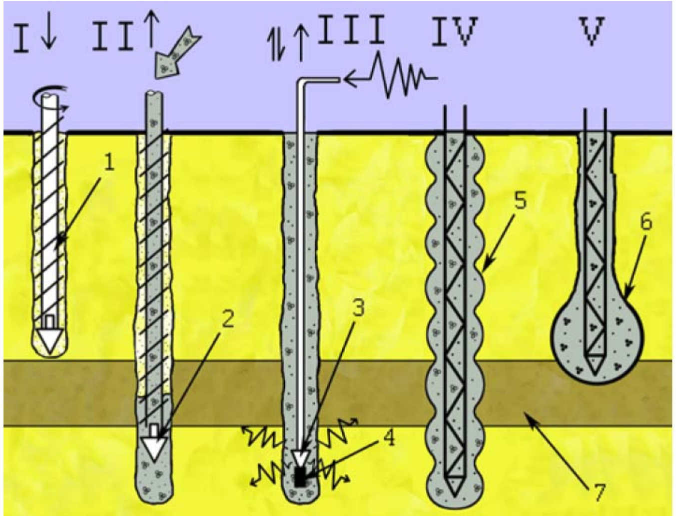

Fig. 4. Construction of pile applying the Geotechnical Electrical Discharge Technology. (I) Drilling; (II) Filling with concrete mixture; (III) Electric discharge; (IV and V) Lowering of reinforcement into hardening concrete mixture.

Session 7b – Case Histories of Geotechnical Earthquake Engineering, Failures and Geotechnical Analysis of Recent Earthquakes

Paper No. 7.01b, EARTHQUAKE INDUCED EXCESS PORE WATER PRESSURES IN THE UPPER SAN FERNANDO DAM DURING THE 1971 SAN FERNANDO EARTHQUAKE, by *A. Sadrekarimi and T. Stark*. This paper reviews the construction and field observations of the behavior of the Upper San Fernando Dam during the 1971 San Fernando earthquake. A simple approach involving Newmark's (1965) and Makdisi-Seed's (1978) permanent deformation and limit equilibrium slope stability analyses are used by the authors to estimate the excess pore water pressures developed in the core and downstream shell areas during the earthquake. The excess pore water pressures are estimated using the actual displacement of the dam, as computed with the aforementioned permanent deformation methods, combined with pseudo-static limit equilibrium analysis. The major difference of this type of analysis with previous studies lies in the assumptions regarding the selection of: (a) the geometry of the failure plane, (b) the liquefiable zones, and (c) the mobilized shear strengths. Taking account of the presence of interbedded sand layers within the fine silt and clay, the authors assume that the central core area was also liquefiable. The results are compared with field measurements. In contrast to previous studies, which indicate development of large excess pore pressure ratios only in the upstream and downstream shells, the results of this study are shown to be consistent with the limited deformation of the dam and the piezometer response during the earthquake. The predicted range of excess pore water pressure ratios r_u in the core area are shown to be in accord with piezometer measurements. However, the predicted range of r_u in the hydraulic fill is substantially larger than the measured: 47% - 33% instead of 12%. According to the authors, this difference could be attributed to the fact that the relevant piezometer was not deep enough to measure the pore water pressure at the failure plane.

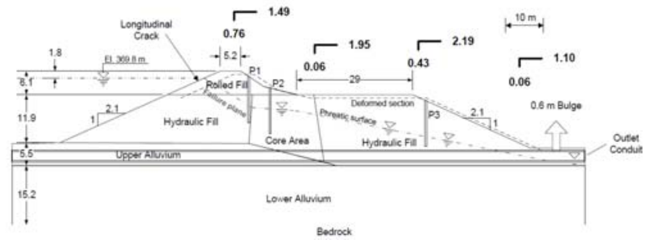

Fig. 5. Cross section of the Upper San Fernando Dam (dimensions in meters).

Paper No. 7.04b, PERFORMANCE OF SOLID WASTE SOIL IN BROUJERD AND SILAKHOR EARTHQUAKE, by *H. Niroumand*. This paper presents a comparison of solid waste without geosynthetic during the Boroujerd and Silakhor earthquakes, and a case of solid waste with geosynthetic during the Boroujerd earthquake. Seismological information about the earthquakes is provided and a qualitative estimation of damages is performed. Post-earthquake condition of soil waste soils is evaluated.

Paper No. 7.12b, MICROZONATION STUDY OF DUZCE, TURKEY, by *D. Manou, M. Manakou, M. Alexoudi, A. Anastasiadis, and K. Pitilakis*. This paper presents the methodology and results of a microzonation study for the city of Düzce (Turkey), conducted after the devastating 1999 M_w7.2 earthquake. After collection and analysis of available geological and geophysical data, a well focused geophysical and geotechnical investigation was conducted, comprising a sufficient number of: (i) shallow and deep boreholes, (ii) seismic down-hole tests, and (iii) array microtremor and ambient noise measurements. Based on all this data, a seismic geotechnical map was constructed, including the geometry of the "seismic bedrock" of the city. Then, a detailed seismic hazard study was conducted on the basis of all available strong ground motion records. Finally, a site effect analysis was undertaken for the seismic scenario of the 1999 earthquake. The latter included a series of conventional 1D equivalent linear analyses. The results of the analyses were processed to come up with an estimation of the spatial distribution of the mean acceleration, velocity and displacement response spectra. Based on the results, the city was divided in seismic zones. For each zone the authors propose mean design acceleration response spectra and all other characteristics of the expected ground response.

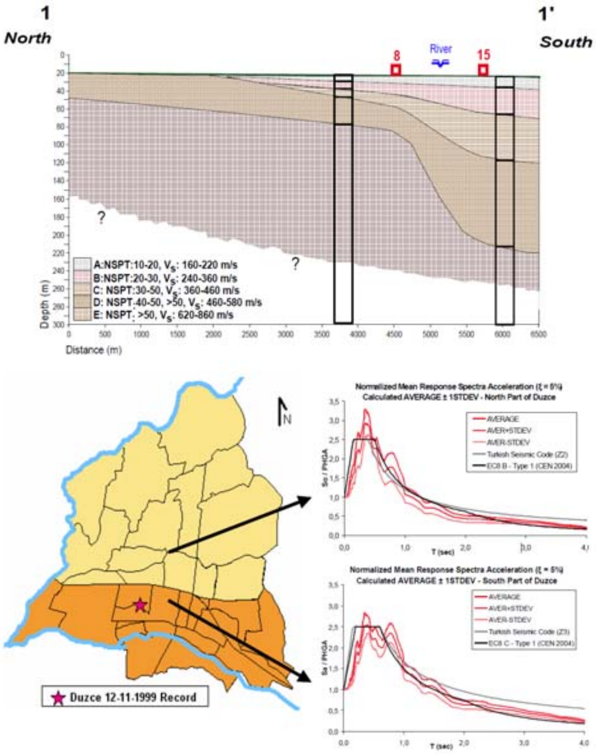

Fig. 6. Typical geotechnical cross section at the NS direction (top) and computed normalized response spectra for the North and the South part of Düzce, compared to EC8 (bottom).

Paper No. 7.14b, GROUND IMPROVEMENT BY DYNAMIC COMPACTION AT A TAILINGS DISPOSAL FACILITY, by *H. Plewes, B. Chambers, T. Jibiki, A. Sy, and R. Friedel*. This paper presents two case histories of ground improvement by dynamic compaction at a mine site in British Columbia, Canada. The two sites included a waste rock dump beneath a new processing plant to reduce settlements beneath the structure foundation, and a potentially liquefiable site at the toe of an existing tailings embankment to increase resistance against liquefaction. Ground improvement at both sites is well documented and described.

Session 7c – Geotechnical Earthquake Engineering Issues in San Diego Region: Seismic Hazard, Onshore and Offshore Faulting, Near Fault and Directivity Effects, Liquefaction and Lateral Spread, Seismic Retrofit Projects, Seismic Design of Large Projects, Deep Canyon Fills, Landslides, Tsunamis.

Paper No. 7.01c, SEISMIC HAZARD EVALUATION FOR DESIGN OF SAN VICENTE DAM RAISE, by *L. Handfelt, I. Wong, P. Thomas, T. Dawson, and J. Zhou*. This paper presents details of the seismic hazard evaluation for the development of design strong ground motions for the final design of the dam raise. Deterministic and probabilistic analyses were performed to represent better all potential seismic sources. Application of Next Generation of Attenuation (NGA) relationships resulted in lower estimates of peak ground accelerations than what were obtained based on the previous attenuation relationships sue to the use of the site-specific shear wave velocities of the foundation materials.

Paper No. 7.02c, FAULT HAZARD CHARACTERIZATION FOR A TRANSPORTATION TUNNEL PROJECT IN CORONADO, CALIFORNIA, by *J. Gingery, S. Rugg, and T. Rockwell*. This paper presents a fault hazard study performed as part of a proposed traffic tunnel project in Coronado, California. The 2.3 km alignment crosses the Coronado fault, which is considered active by the California Geological Survey. Although the location of the Coronado fault offshore of Coronado had been well established through previous studies, the fault had never been definitely located on land. Filed studies included seismic reflection survey, large diameter borings, closely-spaced cone penetration tests (CPT) and a fault trench. This study was the first to positively locate the Coronado fault on land and to show that approximately 29 cm of vertical displacement has occurred in the Holocene.

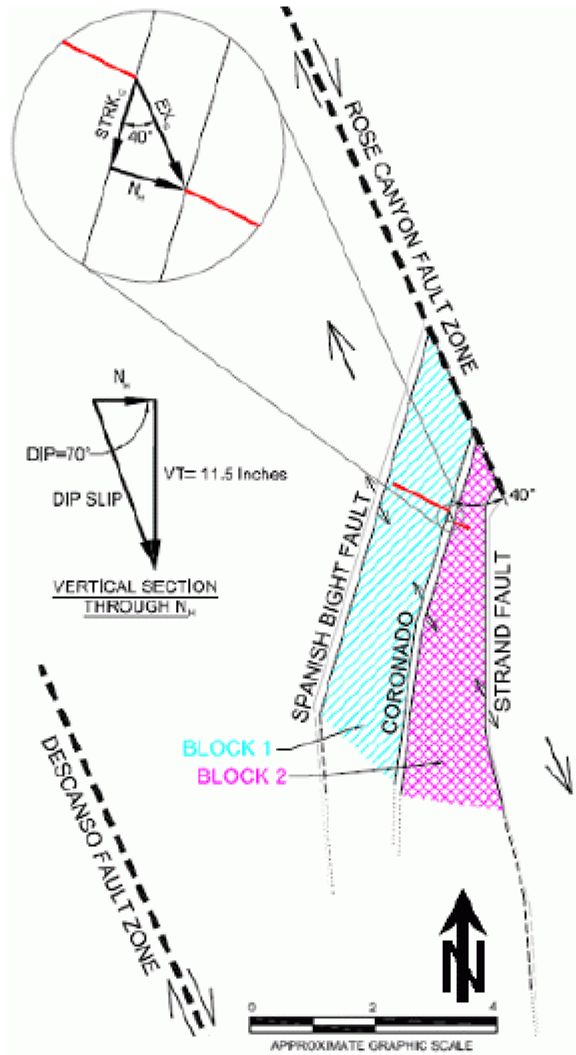

Fig. 7. Diagram showing extensional faulting kinematic model geometry and sense of movement

Paper No. 7.03c, VIBRO REPLACEMENT AND SOIL MIXING GROUND IMPROVEMENTS AT A SHOPPING MALL SITE, by *L. Shao and J. Kinley*. Liquefiable saturated loose sand layers and soft clay layers at a shopping mall site required ground improvement to mitigate liquefaction and large settlements. The paper describes the procedures of ground improvement including vibro replacement and soil mixing. Application of these methods met schedule, regulatory and technical requirements. The paper focuses on the design, production work, and dynamic and static settlement analysis using post-treatment cone penetration tests.

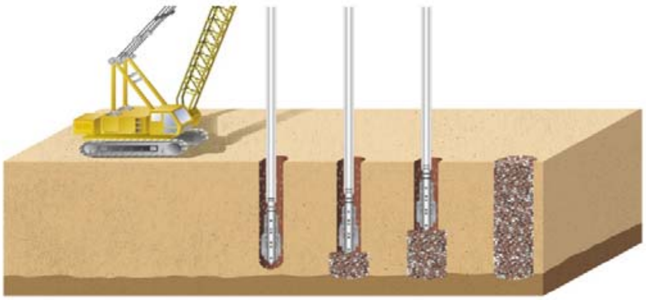

Fig. 8 Vibro Replacement stone column installation procedure following penetration to design depth

Paper No. 7.04c, SAN DIEGO SEISMIC STUDY – LANE FIELD, by *S. Weedon and G. Cannon*. This paper describes the fieldwork including seismic-reflection traverses, forty cone penetration tests, and five small-diameter borings to explore the site for faulting. A detailed fault evaluation was required because the site is within the City of San Diego Downtown Special Fault Zone. The proposed building at the site is a 40-story, mixed-use, retail/hotel with two subterranean parking levels. Fieldwork led to the conclusion that the site was not affected by active or potentially active faulting.

Paper No. 7.05c, VIBRO REPLACEMENT FOR LIQUEFACTION MITIGATION AND AT A STORAGE FACILITY IN CORONADO, CALIFORNIA, by *S. Arora, R. Stroop, and L. Shao*. Vibro replacement stone columns were installed for soil improvement for the construction of a 20,000-square-foot operational storage facility in Coronado, California. The soil improvement program was performed to meet seismic and static performance criteria for spread footings founded on improved soil. CPT testing was performed before and after stone column construction to verify the vibro replacement program. Comparison between pre- and pos-construction CPT's showed remarkable increase in the tip resistance in loose sand layers. Accounting for densification and shear reinforcement, the anticipated post-improvement liquefaction-induced settlement was reduced significantly.

Paper No. 7.06c, THE ROSE CANYON FAULT ZONE IN SAN DIEGO, by *T. Rockwell*. This paper describes the current state of knowledge with respect to the location, slip rate, timing, and magnitude of past large events of the strike-slip Rose Canyon fault within San Diego. Being part of a coastal system of faults that accommodate 6 to 7 mm/yr between San Clemente Island and the mainland, the fault bisects the City of San Diego, and is responsible for the uplift of Mt. Soledad and the subsidence producing the natural harbor of San Diego Bay. According to geologic studies, the late Quaternary slip rate is in the range of 1 to 2 mm/yr, indicating a potential to produce major damage in the city. Paleoseismic trenching in La Jolla and downtown San Diego indicate that the most recent surface rupture occurred only a few hundred years ago, between 1523 and 1769. According to the results of 3D trenching, the fault offset in this seismic event may have been as much as 3 m. Based on this displacement and the slip rate, the average return period is estimated to be of the order of 1500 to 3000 years. However, limited observations suggest that the Rose Canyon fault behaves in a clustered mode, where earthquakes are clustered in time, rather than in a quasi-periodic fashion. According to the author, if this is correct, and considering that the rupture in the past few hundred years appears to have been the first large earthquake in more than 5000 years, San Diego may have entered a renewed period of seismic activity.

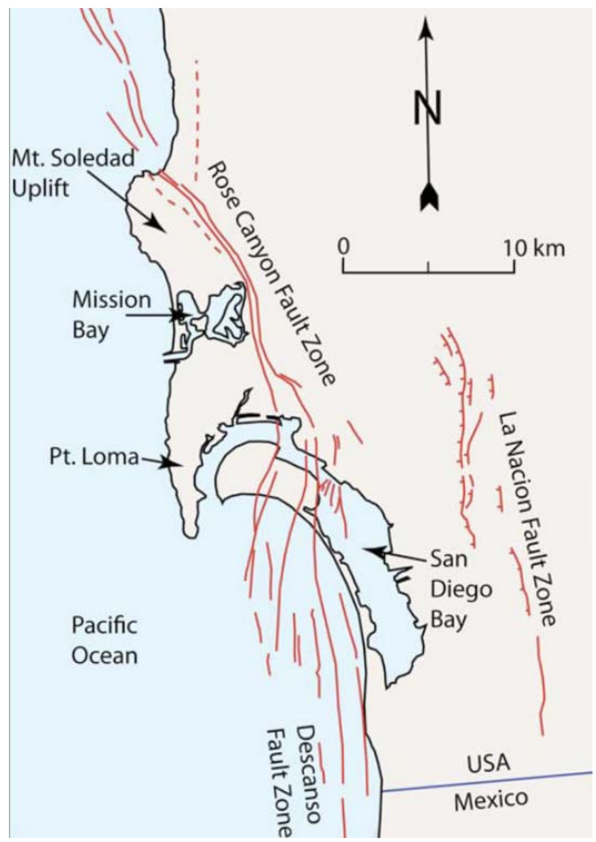

Fig. 9 The Rose Canyon Fault Zone in the San Diego Region.

Paper 7.08c, COMPARISON OF EROSIONAL FEATURES BY TSUNAMI AND WIND WAVES, by *B. Pal and M. Panda*. A detailed comparison of erosional features by tsunami and wind waves is provided. Examples of erosion features by strong wind and the 2004 tsunami are shown on the Indian coasts.

FINAL REMARKS AND TOPICS FOR DISCUSSION

The papers presented in this session cover a wide range of important topics in the area of geotechnical earthquake engineering, including: (a) seismic analysis and retrofit of foundation of bridges and other sub-structures, (b) seismic retrofit projects and procedures in California, (c) failures and geotechnical analysis of recent earthquakes, and (d) geotechnical earthquake engineering issues in the San Diego region, host city of the conference. The papers indicate a high level of technical expertise of the authors and coauthors of the papers. The purpose of the discussion topics below is to establish a discussion and effective exchange of experience and views between authors and conference delegates.

Suggested discussion topics include:

1) Foundation on liquefiable soils
2) Seismic hazard and earthquake ground motions
3) Dam seismic safety
4) Ground improvement for settlement control and liquefaction mitigation
5) Fault hazard studies

ACKNOWLEDGEMENTS

The authors are indebted to the leadership and guidance of Professor Shamsher Prakash for the organization of this important Conference and promoting dissemination and discussion of papers that document essential knowledge for the advance in the field of geotechnical earthquake engineering. Thanks also to Lindsay Lomax Bagnall for her contribution to the organization of this conference and support.