## **TCLEE 2009**

#### Lifeline Earthquake Engineering in a Multihazard Environment

PROCEEDINGS OF THE 2009 TECHNICAL COUNCIL ON LIFELINE EARTHQUAKE ENGINEERING CONFERENCE

> June 28–July 1, 2009 Oakland, California

SPONSORED BY The Technical Council on Lifeline Earthquake Engineering of the American Society of Civil Engineers

> EDITED BY Alex K. K. Tang, P.E. Stu Werner, P.E.



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## Foreword

The TCLEE 2009 Conference was held in Oakland, California from June 28 through July 1, 2009, as the seventh in a series of conferences organized by the Technical Council on Lifeline Earthquake Engineering (TCLEE) of the American Society of Civil Engineers (ASCE). Past TCLEE conferences had focused on seismic performance of lifelines. However, over the years, other major natural hazards (floods, extreme winds, volcanoes, and tsunami) as well as man-made hazards (accidental or deliberate) have also caused significant lifeline disruptions that have had national and even international impacts. All the while, our nation's infrastructure continues to age, which increases its vulnerability to these hazards. In view of this, along with the current focus on revitalizing our nation's infrastructure as a means for economic stimulus, there is now an unprecedented opportunity to modernize our lifelines and reduce risks of unacceptable disruption of lifeline operations due to earthquakes and other natural and man-made hazards.

To address these issues, TCLEE 2009 was developed around a theme entitled *Lifeline Earthquake Engineering in a Multihazard Environment*, and had the following goals:

- 1. To bring together engineers, seismologists, geologists, social scientists, and managers from lifeline agencies, academia, government, and the engineering and planning professions worldwide who are involved in the design, retrofit, analysis, planning, and management of lifeline systems subjected to earthquakes, other natural hazards, and man-made hazards.
- 2. To provide a forum that enables conference attendees to interface, exchange ideas, debate points of view, discuss case studies, methods, and standards, and share experiences, solutions, and lessons learned related to lifelines and their performance under earthquakes and other natural and man-made hazards.
- 3. To explore similarities and differences between the performance of lifelines subjected to earthquakes and other natural and man-made hazards, and the methods used to design, retrofit, analyze, plan, and manage lifelines subjected to these various hazards.
- 4. To enable conference attendees to participate in workshops and field trips in various specialty areas related to the conference theme.
- 5. To introduce industry-standard systems and renowned market applications and products through vendor and organization exhibits.

To meet these goals, TCLEE 2009 included plenary sessions, technical paper presentations, panel discussions, pre-conference workshops, and post-conference

field trips. All of these elements of TCLEE 2009 were specifically planned to address a multitude of topics pertaining to the conference theme and objectives.

These Conference Proceedings contain nearly 150 technical papers that were presented at oral breakout and poster sessions, and were peer reviewed and approved by the Technical Program Committee. These papers addressed the following topics:

- Performance of specific lifeline facilities and systems (electric power, water and wastewater, land and air transportation, seaports, and gas and liquid fuel),
- Analysis and engineering issues that apply across lifelines (e.g., seismic risk analysis, geotechnical earthquake engineering, lifeline interdependence, sustainable lifelines, and performance of various lifeline facilities subjected to blast, fire, volcano, tsunami and geohazards);
- Lifeline risk management project and program planning (project funding issues and asset integrity management);
- Special lifeline research programs (research programs at the Pacific Earthquake Engineering Research Center (PEER) and the MCEER –Earthquake Engineering to Extreme Events (formerly Multidisciplinary Center for Earthquake Engineering Research) and
- Performance of lifelines during major natural hazard events (Hurricane Katrina, Hayward Fault earthquake, and Wenchuan, China earthquake)

We gratefully acknowledge the outstanding contributions of the many individuals who are listed on the following pages. These include the various members of the Conference Steering Committee and Technical Program Committee, the plenary session speakers, the activities chair, the sponsorship chair, and the many individuals from within and outside of TCLEE who organized the pre-planned technical breakout sessions, field trips, and workshops that were key to the technical quality of TCLEE 2009. We particularly thank the Technical Program Committee for their dedication and hard work in reviewing technical papers and organizing technical sessions, as well as Yumei Wang, the TCLEE Executive Committee Chair, for her encouragement, support, and insights throughout this conference planning effort.

In addition, we acknowledge the untiring efforts and dedication of Debby Tucker, conference administrative manager, and the various ASCE staff members listed on the following pages for their excellent administrative support.

Finally, we gratefully thank the TCLEE 2009 sponsors and exhibitors for their generous financial support, which was vital to the success of this conference. We also thank the conference cooperating organizations for their in-kind support of TCLEE

2009. All of these supporters of TCLEE 2009 (as of April 6, 2009) are listed on the following pages.

The TCLEE 2009 Conference Organizers were gratified with the outstanding technical papers, workshops, and field trips that comprised this conference, and with the lively and stimulating discussions that occurred throughout the conference. We hope that this will encourage continued interchanges among practitioners and researchers involved in the reduction of risks to lifelines from earthquakes and other natural and man-made hazards. Such interchanges will greatly facilitate the further improvement of practices and the state of knowledge for reducing lifeline risks from all of these hazards.

In closing, the TCLEE 2009 Conference was dedicated to LeVal Lund, who was a leader in lifeline earthquake engineering throughout his career and a key member of TCLEE for many years. Those of us in TCLEE who had the opportunity to know and work with LeVal over the years have benefitted greatly from his insights, his encouragement, and his friendship.

Stu Werner Conference Chair Alex Tang Technical Program Committee Chair

## Acknowledgments

#### **ORGANIZING COMMITTEE**

TCLEE 2009 was organized and convened by ASCE under the direction of the Technical Council on Lifeline Earthquake Engineering. The Conference Organizing Committee consisted of the following members:

#### Conference Chair

Stuart D. Werner, P.E., F.ASCE, Seismic Systems & Engineering Consultants

#### **Technical Program Chair**

Alex K. K. Tang, P.E., F.ASCE, L&T Engineering & Project Management

#### **Steering Committee**

Yousef Bozorgnia, Ph.D., M.ASCE, University of California at Berkeley Reginald DesRoches, Ph.D., M.ASCE, Georgia Institute of Technology Curtis Edwards, P.E., F.ASCE, Psomas Andre Filiatrault, Ph.D., P.Eng, M.ASCE, State University of New York at Buffalo

Ian M. Friedland, P.E., M.ASCE, Federal Highway Administration
Hope A. Seligson, A.M.ASCE, MMI Engineering
Yumei Wang, P.E., F.ASCE (Chair), Oregon Dept. of Geology and Mineral Industries

#### **Technical Program Committee**

Thomas Cooper, P.E., M.ASCE, PB Americas
Curtis Edwards, P.E., F.ASCE, Psomas
William F. Heubach, P.E., M.ASCE, City of Bellevue, WA
John P. Masek, P.E., S.E., M.ASCE, VIE Consultants, Inc. and Weber Basin Water Conservancy District
Nason McCullough, Ph.D., P.E., M.ASCE, CH2M Hill
Peter W. McDonough, P.E., M.ASCE, Questar Corporation
Anshel J. Schiff, Ph.D., M.ASCE, Stanford University
Alex K.K. Tang, P.E., F.ASCE, (Chair) L&T Engineering & Project Management

#### <u>Activities Chair</u>

Ahmed Nisar, P.E., MMI Engineering

<u>Sponsorship Chair</u> Stuart Nishenko, Ph.D., Pacific Gas & Electric Company

#### PLENARY SESSION SPEAKERS

The following speakers substantially enhanced the technical quality of TCLEE 2009 through their outstanding presentations at the conference plenary sessions.

S. Massoud Amin, University of Minnesota John R. Hayes, National Institute of Standards and Technology Blaine D. Leonard, Utah Department of Transportation and President-Elect of ASCE Thomas D. O'Rourke, Cornell University Brian Pallasch, American Society of Civil Engineers Chris D. Poland, Degenkolb Engineers John Scales, World Bank

#### **TECHNICAL SESSION ORGANIZERS**

In addition to the Technical Program Committee, the following individuals from within and outside of TCLEE organized various pre-planned technical breakout sessions that were important elements of the technical quality of TCLEE 2009.

Yousef Bozorgnia, University of California at Berkeley Reginald DesRoches, Georgia Institute of Technology Leonardo Duenas-Osorio, Rice University Martin L. Eskijian, California State Lands Commission Gayle S. Johnson, Halcrow

Daniel Mageau, GeoEngineers Douglas J. Nyman, D.J. Nyman & Associates Thomas D. O'Rourke, Cornell University Jamie E. Padgett, Rice University Glenn J. Rix, Georgia Institute of Technology Yumei Wang, Oregon Department of Geology & Mineral Industries

#### WORKSHOP AND FIELD TRIP ORGANIZERS

In addition to the technical sessions, the conference included workshops and field trips that provided participants with key insights on various issues related to the conference theme and objectives. The following individuals led the planning and organization of these important conference activities:

Mario Baratta, SBC Global Robert Green, URS Corporation James Lienkaemper, U.S. Geologic Survey Kuo-Ean Lin, U.S. Geologic Survey Ahmed Nisar, MMI Engineering (conference activities chair) David Schwartz, U.S. Geologic Survey Robert Tanaka, California Department of Transportation David Wald, U.S. Geologic Survey

#### **ADMINISTRATIVE SUPPORT**

The TCLEE 2009 conference would not have been possible without the excellent administrative support of the following individuals who were retained by or are on the staff of the American Society of Civil Engineers:

Debra Tucker, *Debra Tucker Associates, LLC* (TCLEE 2009 Conference Manager) Tenzing Barshee, *ASCE* Joanna Colbourne, *ASCE* Lucy King, *ASCE* Jeffrey Sandersen, *ASCE* Robin Schuldenfrei, *Robin Graphics* John Segna, *ASCE* 

#### SUPPORTING AGENCIES

The financial support and in-kind support of the following organizations were essential to TCLEE 2009, and are gratefully acknowledged.

Sponsors (as of April 12, 2009)

Platinum – Degenkolb Engineers

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#### Silver –

Earthquake Engineering Research Institute Pacific Gas & Electric Company T.Y. Lin International

#### Bronze –

East Bay Municipal Utility District MCEER -- Multidisciplinary Center for Earthquake Engineering to Extreme Events Research Pacific Earthquake Engineering Research Center Port of Anchorage Port of Oakland VIE Engineering

#### **General Sponsor -**

Earth Mechanics, Inc.

#### Exhibitors (as of April 12, 2009)

California Emergency Management Agency Earthquake Engineering Research Institute Fyfe Co. LLC Hayward Baker Inc. Layne Geoconstruction Maccaferri, Inc. MCEER -- Earthquake Engineering to Extreme Events NCEES Nilex Construction SENSR TNO Diana BV

#### **Cooperating Organizations**

California Department of Transportation Earthquake Engineering Research Institute Federal Emergency Management Agency MCEER –Earthquake Engineering to Extreme Events International Association of Emergency Managers U.S. Army Corp. of Engineers, Engineering Research and Development Center U.S. Geological Survey Utah Seismic Safety Commission Western States Seismic Policy Council

## Dedication



#### Le Val Lund, Jr. 1923 – 2007

Le Val Lund was a passionate and dedicated champion of lifeline earthquake engineering. His lifetime commitment to earthquake engineering resulted in many important public safety contributions and the engagement of dozens of younger engineers into this field. Le Val was also a key leader in TCLEE from its inception and throughout much of his professional life. These Conference Proceedings are dedicated in Le Val Lund's honor.

He was born on February 24, 1923 at French Hospital, Chinatown, in Los Angeles, California. In 1947, Le Val obtained his Bachelor's of Science degree in Civil Engineering from the California Institute of Technology, and then obtained his Master of Science in Civil Engineering from the University of Southern California.

Le Val was hired by Los Angeles Department of Water and Power (DWP) in July 1947, and retired in April 1989 after almost 42 years of service. During his tenure at DWP, Le Val contributed substantially to meeting the public safety and fire protection needs of the City of Los Angeles. He was active in developing new methods of soil and dam analysis, with emphasis on protecting water supplies and public safety. Le Val's professional organization activities included membership in Water and Power Associates (where he was a longtime Board member and also served as President), as well as the American Waterworks Association and the Earthquake Engineering Research Institute.