INTERNATIONAL EFFORTS IN LIFELINE EARTHQUAKE ENGINEERING

Edited by
Craig Davis, Xiuli Du, Masakatsu Miyajima, and Liping Yan




Technical Council on Lifeline Earthquake Engineering
Monograph No. 38

ASCE

International Efforts in Lifeline Earthquake Engineering

Proceedings of the Sixth China-Japan-US Trilateral Symposium on Lifeline Earthquake Engineering

SPONSORED BY
Technical Council on Lifeline Earthquake Engineering

EDITED BY
Craig Davis
Xiuli Du
Masakatsu Miyajima
Liping Yan

Monograph No. 38

ASCE

Published by the American Society of Civil Engineers

Library of Congress Cataloging-in-Publication Data

Published by American Society of Civil Engineers
1801 Alexander Bell Drive
Reston, Virginia 20191
www.asce.org/pubs

ISBN 978-0-7844-1323-4 (print)
Manufactured in the United States of America.

Photo credits (top left and moving clockwise): Wikimedia Commons; USAID Indonesia; Craig A. Davis; and Matthew M. Bradley, U.S. Navy

TCLEE Monograph Series

Publications in print may be purchased from ASCE via telephone at 1-800-548-ASCE (2723) or online at www asce org/bookstore The TCLEE Web site is www asce org/tactclee

No 1 Recent Lifeline Seismic Risk Studies, Kiremidjian, Anne S , Editor, 1990

No 2 Seismic Lost Estimates for a Hypothetical Water System, A Demonstration Project, Taylor, Craig E , Editor, August 1991

No 3 Guide to Post-Earthquake Investigations of Lifelines, Schiff, Anshel J , Editor, August 1991

No 4 Lifeline Earthquake Engineering, Proceedings of the 3rd U S Conference on Lifeline Earthquake Engineering, August 22–23, 1991, Los Angeles, CA, Cassaro, Michael, Editor, August 1991

No 5 Lifeline Earthquake Engineering in the Central and Eastern United States, Ballantyne, Donald, Editor, September 1992

No 6 Lifeline Earthquake Engineering, Proceeding of the 4th U S Conference on Lifeline Earthquake Engineering, August 10–12, 1995, San Francisco, CA, O'Rourke, Michael J , Editor, August 1995

No 7 Critical Issues and State of the Art on Lifeline Earthquake Engineering, Schiff, Anshel J and Buckle, Ian, Editors, October 1995

No 8 Northridge Earthquake: Lifeline Performance and Post-Earthquake Response, Schiff, Anshel J , Editor, August 1995

No 9 Seismic Design for Natural Gas Distributors, McDonough, Peter W , August 1995

No 10 Methods of Achieving Improved Seismic Performance of Communications Systems, Tang, Alex, and Schiff, Anshel J , Editors, September 1996

No 11 Guide to Post-Earthquake Investigation of Lifelines, Schiff, Anshel J , Editor, July 1997

No 12 Seismic Guidelines for Ports, Werner, Stuart D , Editor, March 1998

No 13 Overcoming Barriers: Lifeline Seismic Improvement Programs, Taylor, Craig E , Mittler, Elliott, and Lund, Le Val, September 1998

No 14 Hyogo-Ken Nambu Earthquake of January 17, 1995—Lifeline Performance, Schiff, Anshel J Editor, 1998

No 15 Guidelines for the Seismic Evaluation and Upgrade of Water Transmission Facilities, Eidinger, John M and Avila, Ernesto A , Editors, January 1999

No 16 Optimizing Post-Earthquake Lifeline System Reliability (Proceedings of the 5th U S Conference on Lifeline Earthquake Engineering, Seattle, Washington, August 12–14, 1999), Elliott, William M , and McDonough, Peter W , Editors, August 1999

No 17 Ismit (Kocaeli), Turkey Earthquake of August 16, 1999, Including Duzce Earthquake of November 12, 1999—Lifeline Performance, Tang, Alex K , Editor, September 2000

No 18 Chi-Chi, Taiwan, Earthquake of September 21, 1999—Lifeline Performance, Schiff, Anshel J , and Tang, Alex K , Editors, October 2000

No 19 Gujarat (Kutch) India, M7 7 Earthquake of January 26, 2001 and NAPA M5 2 Earthquake of September 3, 2000, Eidinger, John M , Editor, June 2001

No 20 The Nisqually, Washington, Earthquake of February 2001—Lifeline Performance, McDonough, Peter W , Editor, February 2002

No 21 Acceptable Risk Process—Lifelines and Natural Hazards, Taylor, Craig E , and VanMarcke, Erik H , Editors, March 2002

No 22 Seismic Screening Checklists for Water and Wastewater Facilities, Heubach, William F , Editor, September 2002

No 23 Atico, Peru Mw 8 4 Earthquake of June 23, 2001, Curtis L Edwards, Editor, October 2002

No 24 Lifeline Performance of El Salvador Earthquakes of January 13 and February 13, 2001, Le Val Lund, Editor and Carl Sepponen, Editor, September 2002

No 25 Advancing Mitigation Technologies and Disaster Response for Lifeline System: Proceedings of the Sixth U S Conference and Workshop on Lifeline Earthquake Engineering, Beavers, J E , Editor, August 2003

No 26 Fire Following Earthquake, Scawthorn, Charles, Eidinger, John M , and Schiff, Anshel J , Editors, 2005

No 27 Zemmouri, Algeria, Mw 6 8 Earthquake of May 31, 2003, Edwards, Curtis L , Editor, 2004

No 28 San Simeon Earthquake of December 22, 2003 and Denali, Alaska, Earthquake of November 3, 2002, Yashinsky, Mark, Editor, Lund, Le Val, Co Editor, 2004

No 29 Hurricane Katrina: Performance of Transportation Systems, DesRoches, Reginald, Editor, 2006

No 30 Sumatra-Andaman Islands Earthquake and Tsunami of December 26, 2004 Lifeline Performance, Strand, Carl and Masek, John, Editors, 2007

No 31 Kashiwazaki, Japan Earthquake of July 16, 2007 Lifeline Performance, Tang, Alex K K and Schiff, Anshel J , Editors, 2007

No 32 Pisco, Peru Earthquake of August 15, 2007 Lifeline Performance, Tang, Alex K K and Johansson, Jorgen, Editors, 2007

No 33 Pacific Northwest Storms of December 1–4, 2007: Lifeline Performance, edited by Teresa Elliott, P E , and Alex K Tang, P E

No 34 Seismic Resilience of Natural Gas Systems: Improving Performance, edited by Peter W McDonough, P E

No 35 Haiti M_w 7 0 Earthquake of January 12, 2010: Lifeline Performance, edited by Curtis L Edwards, P E

No 36 Chile Earthquake of 2010: Performance of Lifelines, edited by Alex K Tang and John Eidinger

No 37 Padang, West Sumatra, Indonesia, Earthquake of 2009: Lifeline Performance, edited by Alex K Tang

No 38 International Efforts in Lifeline Earthquake Engineering: Proceedings of Sixth China-Japan-US Trilateral Symposium on Lifeline Earthquake Engineering, edited by Craig Davis, Xiuli Du, Masakatsu Miyajima, and Liping Yan

Other TCLEE Publications

Duke, C Martin, Editor, The Current State of Knowledge of Lifeline Earthquake Engineering, Proceedings TCLEE Specialty Conference, August 30–31, 1977, Los Angeles, CA, (Later designated as the 1st U S Conference on Lifeline Earthquake Engineering), August, 1977

Dowd, Munson, Editor, Annotated Bibliography on Lifeline Earthquake Engineering, 1980

Smith, D J, Jr , Editor, Lifeline Earthquake Engineering, The Current State of Knowledge 1981, Proceedings of the Second TCLEE Specialty Conference, August 20–21, 1981, Oakland, CA, (Later designated as the 2nd U S Conference on Lifeline Earthquake Engineering), August 1981

Hall, William J , Advisory Notes on Lifeline Earthquake Engineering, 1983

Nyman, Douglas, NSF Principal Investigator, Guidelines for the Seismic Design of Oil and Gas Pipelines Systems, TCLEE Committee on Gas and Liquid Fuels, 1984

Cooper, James, Editor, Lifeline Earthquake Engineering Performance, Design and Construction, 1984

Cassaro, Michael and Martinez-Romero, E , Editors, The Mexico Earthquake, 1985, Factors Involved and Lessons Learned, 1986

Eguchi, Ronald and Crouse, C B , Lifeline Seismic Risk Analysis—Case Studies, 1986

Wang, Leon R L and Whitman, Robert, Seismic Evaluation of Lifeline Systems—Case Studies, 1986

Cassaro, Michael and Cooper, James, Editors, Seismic Design and Construction of Complex Civil Engineering Systems, 1988

Werner, Stuart D and Dickenson, Stephen E , Editors, Hyogo-Ken Nambu (Kobe) Earthquake of January 17, 1995: A Post-Earthquake Reconnaissance of Port Facilities, TCLEE Ports Committee, 1996

ASCE Manual

Schiff, Anshel J , Editor, Guide to Improved Earthquake Performance of Electric Power Systems, ASCE Manual 96

TCLEE Earthquake Investigation Reports

TCLEE has also prepared numerous earthquake reports that have appeared in other publications References to these reports and 10 short reports associated with TCLEE monographs can be viewed on the ASCE/TCLEE Web site address given below The 10 short reports are each about 5 to 15 pages long and contain a summary of main observations and some pictures They can be downloaded at *www.asce.org/tactclee.*

Preface

The Sixth China-Japan-US Trilateral Symposium on Lifeline Earthquake Engineering (Symposium) was held in Chengdu, China from May 28 to June 1, 2013. The Symposium attracted 114 participants, 20 of whom were students, consisting of 10 delegates representing the United States, 13 from Japan, and 91 from China. This Symposium included participants from three additional countries—New Zealand, Turkey, and Canada. The Beijing University of Technology, China, served as primary organizer and hosted this sixth Symposium and co-organized in collaboration with Kanazawa University, Japan and the University of Southern California, USA. Professor Xiuli Du of Beijing University of Technology took the role of chief organizer, and Professor Masakatsu Miyajima of Kanazawa University and Dr. Craig A. Davis of Los Angeles Department of Water and Power (acting as representative for the University of Southern California) served as coordinators for Japan and US, respectively.

This Symposium was organized in cooperation with the Southwest Jiaotong University, China, Shanghai Institute of Disaster Prevention and Relief, China, Research Institute of Lifeline Engineering, Inc., Japan, Lifeline Network, Kansai (LiNK), Japan, American Society of Civil Engineers Technical Council on Lifeline Earthquake Engineering (TCLEE), US, and the International Association of Chinese Geotechnical Engineers (IACGE), US. The National Natural Science Foundation of China provided support for the Symposium.

The first China-Japan Symposium on Lifeline Earthquake Engineering was held in 1990 at Beijing, China on the cooperative research between the Central Research Institute of Building and Construction in China and Kobe University in Japan containing wider researchers and engineers in China and Japan who were interested in Lifeline Earthquake Engineering. The second as a trilateral Symposium of China, Japan, and US joint programs was held in 1994 at Xi'an, China under the official US-China protocol program on cooperative earthquake engineering studies. The third, fourth, and fifth Symposiums were held in 1998 at Kunming, 2002 at Qingdao, and 2007 at Haikou, China, respectively.

The objective of this sixth Symposium was to provide a forum for professional lifeline earthquake engineers and researchers in China, Japan, United States, and elsewhere for mutual exchange of recent results of main investigations on lifeline earthquake engineering, including water, wastewater, gas and liquid fuels, electric power, telecommunication, and transportation systems. Transportation includes roads and highways, ports (sea and air) and harbors, rail, and other transport systems and critical components in which communities are dependent upon. Recent severe earthquakes including 2008 China, 2009 Indonesia, 2010 Haiti, 2010 Chile, 2010-2011 New Zealand sequence, and the 2011 Japan earthquakes caused not only the direct losses of damaged lifeline facilities, but also severe indirect losses and community impacts caused by the interruption and long-term restoration of lifeline

system functions. Seismic resilience incorporates the systemic loss and temporal recovery and is therefore a very important issue for managing community impacts and the physical and functional damages related to lifelines. The issue of seismic resilience for lifelines was emphasized in this sixth Symposium.

In the Symposium, three keynote lectures, three invited presentations, and 52 technical papers were presented. The keynote lectures were given by Professor Li Jie, Tongji University, Shiro Takada, Professor Emeritus, Kobe University, and Alex Tang, President, L&T Consulting. The invited presentations were given by Professor Tao Lianjin, Beijing University of Technology, Professor Nobuoto Nojima, Gifu University, and Dr. Craig Davis, Manager, Los Angeles Department of Water and Power.

Many papers were presented by younger practitioners, researchers, and students, showing how interest in lifeline earthquake engineering practice and research continues to grow. These proceedings contain 86 papers, including those presented at the Symposium. The papers cover a wide variety of topics relevant to lifeline earthquake engineering including: seismicity, ground motions, and site effects; seismic performance, modeling, evaluation, and design of water supply, sewage, electric power, gas and liquid fuel, telecommunication, and transportation systems and their components; seismic reliability and post-earthquake serviceability, recovery, and resilience of lifeline systems; hospitals; lifeline interactions; fire following earthquake; tunnels and underground structures; geotechnical and structural earthquake behavior related to lifelines; seismic testing and analysis for lifeline components and foundations (e.g., pipes, bridges, etc.); tsunami impacts and scour.

The purpose of these proceedings is to publish the high quality work that is being undertaken internationally in lifeline earthquake engineering and presented at the Symposium. The papers were first intended to initiate and foster discussion and intellectual exchange during the Symposium. Following the Symposium these proceedings are intended to make the papers available to others. This is the first time the proceedings from this series of lifeline earthquake engineering Symposiums has been formally published and engineering indexed. To ensure high caliber papers, each paper submitted underwent a stringent review for technical, grammatical, and format aspects. Each paper underwent at least two levels of review. The papers were screened by members of the Technical Committee from their respective countries to ensure each was original, pertinent to the Symposium, understandable and written in good English, and had good technical quality providing an important contribution to lifeline earthquake engineering. The papers from China were also reviewed and edited by English language technical editors. The resulting works provided a high quality experience for Symposium attendees and helped foster a good discussion and exchange of practice, experiment, and theoretical knowledge.

An important point on the limited understanding of the term “lifeline earthquake engineering” in the Chinese technical community was identified and discussed during the Symposium. In China, lifeline earthquake engineering primarily refers to piping systems, such as water and sewer, whereas in the US and Japan lifeline earthquake engineering includes water, wastewater, gas and liquid fuel,

electric power, telecommunication, and transportation systems. This cultural difference in definition limits the participation and advancement of this field within China. In China the non-pipeline networks fall into the field of "infrastructure earthquake engineering." To help foster the needed lifeline technical advancements in China, the Symposium title may be best interpreted into the Chinese language as "Lifeline and Infrastructure Earthquake Engineering" along with clear descriptions that the infrastructure term is intended to correlate with the American and Japanese understanding of lifeline systems as previously described, and not overlap detailed building, industrial, or general geotechnical and structural design or research.

In addition, to further foster development in lifeline earthquake engineering, a suggestion was made to create an international association for lifeline and infrastructure engineering based in the United States and include group members from Asian-Pacific countries. This is intended to enhance the international collaboration and development in lifeline and infrastructure engineering research and practice.

The Seventh China-Japan-US Trilateral Symposium on Lifeline Earthquake Engineering is planned to be held in about two years in China and the host is to be determined. The Symposium concluded with the signing of the resolution printed on the following page.

The contributions of numerous individuals and participants from the participating countries are acknowledged. The outstanding efforts of Dr. Zhao Xu of the College of Architecture and Civil Engineering, Beijing University of Technology, for performing the primary coordinating duties and accomplishing a flawless and smooth running Symposium are gratefully acknowledged.

Editors:

Craig Davis
Los Angeles Department of Water and Power

Xiuli Du
Beijing University of Technology

Masakatsu Miyajima
Kanazawa University

Liping Yan
Los Angeles Department of Water and Power

June 2013

"Resolution"

Sixth China-Japan-US Trilateral Symposium on Lifeline Earthquake Engineering

Chengdu, China, May 28–June 1, 2013

The Sixth China-Japan-US Trilateral Symposium on Lifeline Earthquake Engineering was held in Chengdu, China, May 28 to June 1, 2013. The Symposium attracted 114 participants, including 20 Students, consisting of 10, 13, and 91 delegates from the US, Japan, and China, respectively.

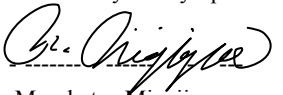
This Symposium was the sixth collaboration of lifeline earthquake engineering among researchers from the US, Japan, and China that started in 1990 in Beijing, China. This Symposium attracted participants from three additional countries, New Zealand, Turkey, and Canada. The Beijing University of Technology, China served as primary organizer and hosted this Symposium and co-organized in collaboration with Kanazawa University, Japan and the University of Southern California, USA. Prof. Xiuli Du of Beijing University of Technology took the role of chief organizer, and Prof. Masakatsu Miyajima of Kanazawa University and Dr. Craig A. Davis of Los Angeles Department of Water & Power (acting as representative for the University of Southern California) served as coordinators for Japan and US, respectively.

In the Symposium, three keynote lectures, three invited presentations, and 52 technical papers were presented. Many papers were presented by younger practitioners, researchers, and students, showing growing interest in lifeline earthquake engineering research and practice. This Symposium identified needs for advancing lifeline earthquake engineering technology in major engineering projects and improving entire lifeline networks. The sessions created good discussion and collaboration among participants. A variety of technical exchanges was fostered through this Symposium and initiated collaborations between different international organizations. A significant step forward for this Symposium is the first proceedings publication by the American Society of Civil Engineers with Engineering Indexing.

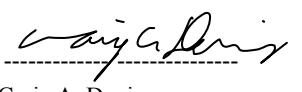
The coordinators of this Symposium believe the following should be pursued:

* The 7th Symposium will be titled in Chinese characters as "7th China-Japan-US Trilateral Symposium on Lifeline and Infrastructure Earthquake Engineering"; but will remain as "… Lifeline Earthquake Engineering" in Japanese and English.
* Create an international association for lifeline and infrastructure engineering based in the United States, to include group members from Asian-Pacific Countries, which can enhance the international collaboration and development in lifeline and infrastructure engineering research and practice, and
* The 7th Symposium should be held in 2 years (in 2015) and hosted either or jointly by Tongji University, Harbin Institute of Technology, or the Southwest Jiaotong University. The host can identify the Symposium location.

Xiuli Du
Coordinator, China



Masakatsu Miyajima
Coordinator, Japan



Craig A. Davis
Coordinator, USA