HAITI M_w 7.0 EARTHQUAKE OF JANUARY 12, 2010 Lifeline Performance

Edited by Curtis L. Edwards



Technical Council on Lifeline Earthquake Engineering Monograph No. 35



This is a preview. Click here to purchase the full publication.

Haiti M_w 7.0 Earthquake of January 12, 2010

Lifeline Performance

EDITED BY Curtis L. Edwards, P.E.

SPONSORED BY Technical Council on Lifeline Earthquake Engineering Monograph No. 35



Published by the American Society of Civil Engineers

This is a preview. Click here to purchase the full publication.

Cataloging-in-Publication data on file with the Library of Congress.

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

Any statements expressed in these materials are those of the individual authors and do not necessarily represent the views of ASCE, which takes no responsibility for any statement made herein. No reference made in this publication to any specific method, product, process, or service constitutes or implies an endorsement, recommendation, or warranty thereof by ASCE. The materials are for general information only and do not represent a standard of ASCE, nor are they intended as a reference in purchase specifications, contracts, regulations, statutes, or any other legal document.

ASCE makes no representation or warranty of any kind, whether express or implied, concerning the accuracy, completeness, suitability, or utility of any information, apparatus, product, or process discussed in this publication, and assumes no liability therefor. This information should not be used without first securing competent advice with respect to its suitability for any general or specific application. Anyone utilizing this information assumes all liability arising from such use, including but not limited to infringement of any patent or patents.

ASCE and American Society of Civil Engineers-Registered in U.S. Patent and Trademark Office.

Photocopies and permissions. Permission to photocopy or reproduce material from ASCE publications can be obtained by sending an e-mail to permissions@asce.org or by locating a title in ASCE's online database (http://cedb.asce.org) and using the "Permission to Reuse" link.

Copyright © 2012 by the American Society of Civil Engineers. All Rights Reserved. ISBN 978-0-7844-1240-4 (paper) ISBN 978-0-7844-7695-6 (PDF e-book) Manufactured in the United States of America.

 18 17 16 15 14 13 12 11
 1 2 3 4 5

This is a preview. Click here to purchase the full publication.

TCLEE Monograph Series

These publications 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.

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, contain a summary of main observations and some pictures. They can be downloaded at *www.asce.org/tactclee*.

v

Contents

Preface		ix
Con	tributors	Х
1.	INTRODUCTION	
1.1	Earthquake Highlights	1
1.2	Lessons Learned	5
1.3	Investigation Team	6
1.4	Web Addresses	7
1.5	Abbreviations	7
2.	SEISMOLOGY AND GEOTECHNICAL ISSUES	
2.1	Seismology	8
2.2	Geotechnical Issues	12
2.3	References	13
3.	WATER, WASTEWATER, AND DRAINAGE SYSTEMS	
3.1	Description of Systems: Water Supply, Wastewater Disposal, and Drainage	15
3.2	Earthquake Performance	18
3.3	Restoration and Future Plans	34
3.4	Major Observations and Recommendations	35
3.5	Acknowledgments	36
4.	ENERGY SECTOR	
4.1	Description of System	37
4.2	Overview of System Performance	37
4.3	Recommendations	48
4.4	Acknowledgments	49
5.	TELECOMMUNICATIONS SECTOR	
5.1	Description of System	50
5.2	PSTN Wireline Telecommunications	51
5.3	Wireless Telecommunications	53
5.4	Major Observations and Recommendations	54
5.5	References	56
6.	ROADS AND BRIDGES	
6.1	Description of System	57
6.2	Overview of System Performance	57
6.3	Site 1—Highway 3 Near Peligre Dam (N72° 2' 23.6"; W18° 54' 05.6")	57

vii

6.4	Site 2—Highway 1 Near Arcahaie	58
6.5	Site 3—Bridge on Highway 2 West of Leogane (N72° 43' 38.23";	
	W18° 25' 21.9")	59
6.6	Site 4—Landslide on Highway 2 (N72° 48' 50.15"; W18° 25' 46.7")	63
6.7	Sites 5 and 6—Highway 2 Damage West of Leogane (N72° 37' 56.9";	
	W 18° 28' 24.2" and N72° 43' 28.5"; W 18° 25' 23.5")	64
6.8	Site 7—Landslide on Highway 2 (N72° 48' 30.6"; W 18° 25' 33.4")	71
6.9	Site 8—Landslide at Road in Boutillier (N72.320043°; W 18.4989°)	74
6.10	Major Observations and Lessons Learned	77
7.	PORTS, MARINE OIL TERMINALS, AND AIRPORTS	
7.1	Description of Systems	78
7.2	Overview of System Performance	80
7.3	Post-Earthquake Repair and Recovery	114
7.4	Major Observations and Recommendations	118
7.5	Acknowledgments	119
8.	HOSPTIALS AND MEDICAL SERVICES	
8.1	Description of System	120
8.2	Overview of System Performance	120
8.3	Electrical Power Systems: Commercial, Emergency, and Solar	139
8.4	Water Systems	146
8.5	Wastewater Systems	150
8.6	Communications Systems: External and Internal	150
8.7	Heating, Ventilating, and Air Conditioning Systems	151
8.8	Natural Gas and Propane Gas Systems	154
8.9	Patient Transportation Systems	154
8.10	Medical Gas Systems	154
8.11	Critical Equipment	155
8.12	Fire Suppression Systems	155
8.13	Hazardous Material	155
8.14	Security Systems	155
8.15	Emergency Preparedness, Response, and Recovery	156
8.16	Conclusions, Observations, and Recommendations	157
	Acknowledgments	158
8.18	References	158
Index		161

viii

Preface

The Earthquake Investigations Committee of the Technical Council of Lifeline Earthquake Engineering (TCLEE), American Society of Engineers (ASCE), was established to initiate, organize, train for, coordinate, and evaluate the performance of lifelines following earthquakes. Members of the committee are employees of lifeline industries, consulting engineers, and academics from the United States, Canada, Europe, and Asia. Committee members provide services on a voluntary basis. Travel expenses are covered in part by ASCE. Some members' companies may allow for special paid leave and may also help cover travel costs. In addition to the time and expense of the field investigation, members must spend several weeks of their time preparing the reconnaissance report.

Individuals participating in the investigation need not be members of the committee or ASCE but are expected to follow the committee's earthquake investigation practices as described in the ASCE publication *Guide to Post-Earthquake Investigation of Lifelines* and the July 25, 2009 *ASCE Post-Disaster Assessment Manual*. Members of the investigation team coordinate with other groups and may participate in groups organized by other organizations. They gather performance data, both good and bad, from earthquakes to provide information to help practitioners improve the performance of lifeline systems. The international earthquakes that have been investigated by this committee include 1985 Chile, 1988 Soviet Armenia, 1990 Philippines, 1991 Costa Rica, 1992 Turkey, 1995 Kobe, 1999 Turkey (Izmit), 1999 Chi Chi (Taiwan), 2001 El Salvador, 2001 Peru, 2004 Algeria, 2004 Sumatra, 2007 Kashiwazki Japan, and 2010 Chile. Domestic earthquakes investigated include 1989 Loma Prieta, 1992 Landers, 1994 Northridge, 2000 Napa, 2001 Nisqually, 2002 Denali, and 2003 San Simeon. TCLEE also conducted an investigation of 2006 Hurricane Katrina.

The Earthquake Investigations Committee works closely with the Earthquake Engineering Research Institute (EERI) to provide an abbreviated version of lifeline performance in *Earthquake Spectra*, an EERI publication.

Curtis Edwards, Editor June 2011

Contributors

Curtis Edwards, *Editor*: Introduction, Chapters 1, 6, and 9 Pierre Alex Augustin: Chapter 7 Don Ballantyne: Chapter 3 Bill Bruin: Chapter 7 Rick Carter: Chapters 4 and 5 Brucely Joseph: Chapter 3 Aimee Lavarnway: Chapters 2 and 9 Nason McCullough: Chapter 7 Mark Pickett: Chapter 8 Dave Plum: Chapter 3 Stu Werner: Chapter 7

Due to the nature of post-earthquake investigations, this report may contain inaccuracies or be incomplete, notwithstanding efforts to eliminate errors.