Seismic Hazards & Infrastructure: A Historic Perspective

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ASCE, 2004

Infrastructure Categories

Utility

- Electric Power
- Natural Gas
- Liquid Fuel
- Telecommunications
- Water
- Wastewater

- Transportation
 - Highways
 - Rail
 - Waterways
 - Ports & Harbors
 - Air

Cyber

Grand Challenges for Disaster Reduction

A Report of the Subcommittee on Disaster Reduction

Grand Challenge 4

Recognize and Reduce Vulnerability of Interdependent Critical Infrastructure

Critical Infrastructure

For the Government:

Those facilities that must remain mission operational during periods of national crisis or emergency. [Outside the fence]

For the Private Sector:

What each owner decides. [Inside the fence]

Key Characteristics of Lifeline Systems

- Design based on system performance
- Requirements different than those for buildings
- Multi-jurisdictional regulatory oversight
- Owners/operators have special knowledge



EARTHQUAKE AND FIRE: Two San Francisco Gas and Electric Co. employees view the ruins of Station "B," Third and Townsend streets; INSET: Market Street, between Stuart and Second; April 18-23, 1906.



Milestones

- 1971 San Fernando earthquake (M 6.4) 'birth of lifeline earthquake engineering'
- 1974 Technical Council on Lifeline Earthquake Engineering (TCLEE)

ASCE Technical Council on Lifeline Earthquake Engineering (TCLEE)

Lifelines are the systems and facilities that provide services vital to the function of an industrialized society and important to the emergency response and recovery after a natural disaster. These systems and facilities include communication, electric power, liquid fuel, natural gas, transportation (airports, highways, ports, rail and transit), water, and wastewater.

Purpose:

To advance the state-of-the-art and practice of lifeline earthquake engineering through the following endeavors:

- Participate in the development of guidelines, pre-standards and standards for the seismic design and construction of lifelines;
- Encourage lifeline organizations, industries and associated manufacturers, associations and professionals to consider earthquakes and their impacts in the planning, design, emergency planning and operation of lifelines;
- Serve as a primary resource for establishing broad consensus on lifeline issues;
- Identify and prioritize research needs related to lifeline planning, design, construction and operation; and
- Support and/or conduct programs for education and technology transfer on lifeline seismic issues.

EARTHQUAKE INVESTIGATION ELECTRICAL POWER AND COMMUNICATIONS LIFELINES GAS AND LIQUID FUELS LIFELINES PORT AND HARBOR LIFELINES SEISMIC RISK TRANSPORTATION LIFELINES WATER AND WASTEWATER LIFELINES PUBLICATIONS TCLEE EARTHQUAKE REPORTS

Milestones

- 1977 Creation of NEHRP (Public Law 95-124)
- 1985 BSSC Workshop Abatement of Seismic Hazards to Lifelines An Action Plan
- 1986 National Center for Earthquake Engineering Research (NCEER)
- 1989 NIBS Report Strategies and Approaches for Implementing A Comprehensive Program to Mitigate the Risk to Lifelines from Earthquakes and Other Natural Hazards

Loma Prieta earthquake (M 7.1) - wake up call' for the SF Bay region



California Policy on Acceptable Level of Earthquake Risk*

Each utility shall withstand earthquakes to:

- Provide protection of life
- Limit damage to property, and
- Provide for resumption of utility service in a reasonable and timely manner

California Seismic Safety Commission/CPUC Safety Branch (1992) California Earthquake Loss Reduction Plan (1997) California Utilities and Transportation Systems Earthquake Risk Management Policy Requirements

Policy to manage earthquake risks:

- Program to understand hazards and system vulnerabilities
- Plan to implement risk management options
- Dedicated staff
- Dedicated budget
- Accountability

* California Seismic Safety Commission/CPUC Safety Branch

Milestones

- 1990 NEHRP Reauthorization (Public Law 101-614) FEMA & NIST to develop a plan for adopting design and construction standards for lifelines
- 1991 NIST Workshop on Developing and Adopting Seismic Design and Construction Standards for Lifelines
- 1994 Northridge earthquake (M 6.7)
- 1995 FEMA 271 Plan for Developing and Adopting Seismic Design Guidelines and Standards for Lifelines
- 1997 Pacific Center for Earthquake Engineering Research (PEER)

PEER Lifelines Program

Providing data, models, and methods needed to improve the earthquake reliability and safety of lifelines systems.

Implementation of Research Results

A key feature of the Lifelines Program is that the research results are implemented rapidly by the sponsors of the research.



PEER Lifeline Projects

Substation Equipment & Buildings Research

- Rigid/ Flexible Bus Interactions
 - Theoretical
 - Experimental



- Input Ground Motions for Simulator Testing
- Seismic Qualification and Testing of 230 / 500 kV Disconnect Switches and 196 and 500 kV Transformer Bushings
- Substation Equipment Database Development
- Seismic Assessment Building Guidelines

PEER support for IEEE 693 – Recommended Practice for Seismic Design of Substations

Milestones

- 1997 ASCE Lifeline Policymakers Workshop
- 1998 NCEER become Multidisciplinary Center for Earthquake Engineering Research (MCEER)

American Lifelines Alliance - cooperative agreement between FEMA and ASCE

American Lifelines Alliance

A Public-private Partnership to Reduce Risk to Utility and Transportation Systems from Hazards

www.americanlifelinesalliance.org

General ALA Approach

- Facilitate the creation, adoption, and implementation of national consensus guidelines
- Utilize Industry and Corresponding Advisors to generate project ideas
- Increase awareness at conferences and through focused studies and pilot projects.

American Lifelines Alliance Matrix of Standards and Guidelines for Natural Hazards

COMPONENT

System Reliability⁶ Towers, Masts and Poles

TELECOMMUNICATION SYSTEMS

GUIDE/STANDARD¹

TIA/EIA 222G (2003)

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TIA/EIA 222E wind, ice wind, ice Buried Cables Bell Core earthquake, flood earthquake, flood Underwater Cables Aboveground Cables Bell Core earthquake, wind, ice, snow Earthouake, wind, ice, snow Switching Equipment Bell Core earthquake, fire earthquake, fire SMACNA BSP (Bell System Practice) able Travs earthquake earthquake none none ASCE 7 earthquake, wind, ice, snow earthquake, wind, ice, snow NATURAL HAZARD PROVISIONS^a PORTS AND INLAND WATERWAYS LOADING COMPONENT GUIDE/STANDARD¹ DESIGN EXISTING ASCE TCLEE 12 System Reliabilty earthquake ers/Wharv NCEL R-939 NAVFAC DM-25.1 ASCE TCLEE 12 earthquake earthquake earthquake earthquake NFESC TR-2069SHR earthouake earthquake Breakwaters/Jetties NCEL R-939 earthouake earthquake ASCE TCLEE 12 earthquake earthquake . Sea Walls NCEL R-939 earthquake earthquake ASCE TCLEE 12 earthquake nquake, wind, snow, ice earthquake nquake, wind, snow, ice ٠ Container Handling ASCE-7 IBC. SBC. UBC earthquake, wind, snow, ice earthquake, wind, snow, ice ASCE TCLEE 12 earthquake earthquake • arthquake, wind, snow, ice AISC none² Caroo Movement ASCE-7 earthquake, wind, snow, ice earthquake, wind, snow, ice IBC SBC UBC earthquake, wind, snow, ice arth quake, wind, snow, ice ASCE-ASCE TCLEE 12 earthquake earthquake earthquake earthquake earthquake earthquake Marine Oil Terminals CSLC NEESC TR-2103-SHR earthquake, wind, sno ake, wind, snow, ice ASCE-7 NFPA⁴ w. ice earthquake earthquake HIGHWAYS AND ROADS NATURAL HAZARD PROVISIONS GUIDE/STANDARD COMPONENT LOADING DESIGN EXISTING System Reliabilit EHWA 108 earthquake earthquak Bridges AASHTO earthquake, wind, snow, ice, earthquake, wind, snow, ice, 1000 flood earthquake, wind, snow, ice, flood earthquake, wind, snow, ice, flood • CALTRANS FHWA-RD-94-052 : earthquake earthquake FHWA 106 CALTRANS earthquake earthquake Embankments earthquake earthquake Road Beds Culverts AASHTO none none CALTRANS none² none Tunnel AASHTO CALTRANS none² none none² none Retaining Walls FHWA 106 earthquake earthquake Signs ASCE-7 earthquake, wind, snow, loe earthquake, wind, snow, loe IBC, SBC, UBC earthquake, wind, snow, ice earthquake, wind, snow, ice RAILROAD NATURAL HAZARD PROVISIONS COMPONENT GUIDE/STANDARD¹ LOADING DESIGN EXISTING⁷ System Reliability AREMA Ch. 9 AREMA Ch. 7 AREMA Ch. 8 AREMA Ch. 9 AREMA Ch. 15 Bridges wind wind, ice earthquake wind wind wind, ice earthquake wind Embankments AREMA Ch. 9 earthouake earthquake earthquake Ralis, Ties, and Ballast AREMA Ch. 9 earthquake earthquake earthquake Culverts AREMA Ch. 9 earthquake earthquake earthquake AREMA Ch. 9 Tunnels earthquake earthquake earthquake

LOADING

earthquake, wind, ice

NATURAL HAZARD PROVISIONS¹

earth

uake, wind, snow

DESIGN

earthquake, wind, ice

EXISTING⁷

	IBC, SBC, UBC	earthquake, wind, snow, ice	earthquake, wind, snow, ice	1
				-
ELECTRICAL, MECHANIC ARCHITECTURAL COMP	CAL, AND ONENTS	NATURAL	HAZARD PROVISIONS	
COMPONENT	GUIDE/STANDARD ¹	LOADING	DESIGN	EXISTING ⁷
Elect./Mech. Equip	ASCE-7	earthquake, wind, loe	earthquake, wind, loe	
	ASCE TCLEE 1984	earthquake	earthquake	•
	ASME BPV ³	none ²	earthquake, wind	
	NFPA*	earthquake	earthquake	
	IBC, SBC, UBC	earthquake, wind	earthquake, wind	
	SMACNA	earthquake	earthquake	•
Suspended Cellings	IBC, SBC, UBC	earthquake	earthquake	
Elevated Floors				

NOTES

. Documents in by bold italics indicate that the guidelines were not produced by a consensus process as defined for SDO's approved by the American National Standards Institute

- "none" applies if a guideline or standard does not specifically identify how loads are to be obtained; if a group of standards is referenced, the natural hazard listed may be only covered in one document
- 3. ASME BPV refers to the ASME Boller and Pressure Vessel Code that typically governs the design of all pressurized containers
- 4. NFPA refers to various NFPA standards governing fire protection systems
- 5. AWWA D refers to various AWWA standards governing water storage tanks

ASCE-7

- 6. "System Reliability" is a component of design referring to practices that are specifically developed to provide reasonable assurance that consequences of a natural hazard on system service will meet the gaals established by stakeholders (comers, operators, regulators, insurers, outsomers, and users). Consequences are defined by multiple performance requirements but typically include impact on public safety, duration of service interruption, and costs for repair damage.
- 7. Existing indicates that analysis or design procedures (NOT LOADS) could be applied for existing components
- Loading refers to whether or not specific loads for various natural hazards are defined; "Design" refers to the existence of design and/or analysis procedures that account for loads arising from natural hazards

ALA Manmade Hazards Matrix Summary

ELECTRIC POWER		MANMADE HAZARD PROVISIONS		
COMPONENT	GUIDE/STANDARD	LOADING	DESIGN	EXISTING
System Reliability	\$ Ø	Radiological, Blast, Cyber	Biological, Blast, Cyber	
Transmission Towers	ø	Blast	Blast	
Distribution Poles	8	Blast	Blast	
Buried Conduits	ø	Radiological	Radiological	
Substations	IEEE (1) \$	Chemical	Radiological	
	ø	Radiological		
Elect./Mechanical Equipment	ø	Radiological, Cyber	Radiological, Cyber	

NATUR	RAL GAS	MANMADE HAZARD PROVISIONS		
COMPONENT	GUIDE/STANDARD	LOADING	DESIGN	EXISTING
System Reliability	NPC (2) Ø	Radiological, Blast	Cyber Radiological	
Buried Pipelines	DOT (3) DOT (4) DOT (5) DOT (6)	Blast Blast Blast	Chemical Blast	
Aboveground Piping	DOT (7) DOT (8) DOT (9) DOT (10)	Blast Blast Blast	Chemical Blast	
Compressor Station Piping				
Well Facilities				
Offshore Production Installations	ISO (11) \$	Chemical, Blast		
Elect./Mechanical Equipment	\$ 27	Radiological	Radiological	

OIL PRODUCTS		MANMADE HAZARD PROVISIONS		
COMPONENT	GUIDE/STANDARD	LOADING	DESIGN	EXISTING
	NPC (12)	Cyber	Cyber	
System Reliability	\$			
	ø	Radiological, Blast	Radiological, Blast	
Buried Pipelines	ø	Blast	Blast	
Aboveground Piping	ø	Blast	Blast	
Pumping Station Piping	ø	Blast	Blast	
Well Facilities	ø	Blast	Blast	
Refineries	ø	Blast	Blast	
Storney Tanks	\$	Black		
atorage Tariks	ø	Diase		
Elect./Mechanical Equipment	ø	Radiological, Blast, Cyber		

LNG SYSTEMS		MANMADE HAZARD PROVISIONS		
COMPONENT	GUIDE/STANDARD	LOADING	DESIGN	EXISTING
Sustem Belizbility	\$	Padialagiaal Plast Cubes	Padialagian Plast Cuber	
System Poenability	ø	Radiological, Blast, Cyber	Radiological, blast, cyber	
Piping	ø	Blast	Blast	
Storage Tanks	ø	Blast	Blast	
Elect./Mechanical Equipment	~	Radiological, Blast, Cyber	Radiological, Blast, Cyber	

WATER SYSTEMS (POTABLE & RAW)		MANMADE HAZARD PROVISIONS		
COMPONENT	GUIDE/STANDARD	LOADING	DESIGN	EXISTING
Treatment Units	(13) USACHPPM (14)		Chemical, Biological Biological	
System Reliability	(15)		Chemical, Biological, Radiological, Cyber Chemical, Biological	
Buried Pipelines	(10)			
Aboveground Pipelines				
Pumping Plants	\$			
Storage Tanks	\$			
Well Facilities				

* = Guidelines & Standards not produced by	y an ANSI approved standard developing organization.
A = Quidelines 8 Ctandards penduced by an	ANICI received standard developing complexition

A Colliderines & Standards not produced by an ANSI approved standard developing organization.
 A Colliderines & Standards not produced by an ANSI approved standard developing organization.
 Empty how indicates guidelines and standards related to the specified hazards are not available.
 S = Standards have been identified, but must be purchased for review. See appendices B-M.
 Loading: Whether or not specific loads for various identified hazards are defined.
 Design: Existence of design and/or analysis that account for loads arising specified hazards.
 The Standards have been identified but must be purchased for review. See appendices
 Design: Existence of design and/or analysis that account for loads arising specified hazards.
 Design: Existence of design and/or analysis that account for loads arising georgenerits.
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 Design: Existence of design and/or analysis that account for loads arising appendiced.
 Design: Existence of design and/or analysis that account for loads arising components.
 NPC (2): Securing Oil and Natural Oas infrastructures in the New Economy.
 Dot (4): CFR 40, 192, 614, Damage Prevention Program.
 Dot (6): CFR 40, 192, 614, Damage Prevention Program.
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WASTEWATER SYSTEMS		MANMADE	s	
COMPONENT	GUIDE/STANDARD	LOADING	DESIGN	EXISTING
System Reliability				
Buried Pipelines				
Aboveground Pipelines				
Pumping Plants	NFPA (17) \$	Chemical, Blast		
Storage Tanks	\$			

TELECOMMUNICATIONS SYSTEMS		MANMADE HAZARD PROVISIONS		
COMPONENT	GUIDE/STANDARD	LOADING	DESIGN	EXISTING
System Reliability	SEI (18) \$	Cyber	Cyber	
	ø	Radiological, Blast	Radiological, Blast	
Towers, Masts and Poles	ø	Biological	Biological	
Buried Cables				
Underwater Cables				
Aboveground Cables				
Switching Equipment	ø	Radiological, Cyber	Radiological, Cyber	
Cable Trays				

PORTS AND INLAND WATERWAYS		MANMADE HAZARD PROVISIONS		
COMPONENT	GUIDE/STANDARD	LOADING	DESIGN	EXISTING
Custom Reliability	\$		Blast	
System Reliability	8		Blast	
Riors (M/banaos	\$		Blast	
Tiers/venarees	ø			
Breakwaters/Jetties	ø		Blast	
Sea Walls	ø		Blast	
Container Handling				
Cargo Movement				
Marine Oil	\$		Blact	
Terminals	0		Clast	

HIGHWAYS AND ROADS		MANMADE HAZARD PROVISIONS		
COMPONENT	GUIDE/STANDARD	LOADING	DESIGN	EXISTING
System Reliability				
Bridges	\$			
Embankments				
Road Beds				
Culverts				
Tunnels				
Retaining Walls				
Signs				

RAILROAD		MANMADE HAZARD PROVISIONS			
COMPONENT	GUIDE/STANDARD	LOADING	DESIGN	EXISTING	
System Reliability					
Bridges	\$				
Embankments					
Rails, Ties, and Ballast	\$				
Culverts					
Tunnels					
Signs					

INFRASTRUCTURE INTERDEPENDENCIES		MANMADE HAZARD PROVISIONS		
COMPONENT	GUIDE/STANDARD	LOADING	DESIGN	EXISTING
System Reliability	ø	Chemical, Biological, Radiological, Blast, Cyber	Chemical, Biological, Radiological, Blast, Cyber	

REVISED JANUARY 2003

KEY TO TABLE

DOT (1): CFR 40, 105.8, Transportation of Hazardous Liquids or CO₂ in Pipelines Constructed with other than Steel Pipe. DOT (1): CFR 40, 105.8, Transportation of Hazardous Liquids or CO₂ in Pipelines Constructed with other than Steel Pipe. DOT (10): CFR 40, 102.014, Damage Prevention Program. ISO (11): Petroleum and Gas industries - Control and mitigation of first and explosions on offshore production installations. US Congress (13): Safe Dinking Watare Agents as Threate The Exercise Control Health Perspectives 107:975-984. US Congress (13): Safe Dinking Watare Agents as Threate Potable Water Environ Health Perspectives 107:975-984. US Congress (16): HR 3178 and the Development of Anti-Terrorism Tools for Water Infrastructure. NFPA (17): Standard for Fire Frotection in Wastewater Treatment and Collection Facilities. SEI (18): the CERT Guide to System and Network Security Practices.

Draft map for ASCE 74 Ice thicknesses from freezing rain for a 50-yr return period with concurrent gust speeds



AmericanLifelinesAlliance

A public-private partnership to reduce risk to utility and transportation systems from natural hazards and manmade threats

Guideline for Assessing the Performance of Electric Power Systems in Natural Hazard and Human Threat Events







Milestones

- 2001 September 11
- 2002 ALA transferred to National Institute of Building Sciences (NIBS) Multihazard Mitigation Council (MMC)
- 2003 Department of Homeland Security

Homeland Security Presidential Directive 7: Critical Infrastructure Identification, Prioritization, and Protection

2006 National Infrastructure Protection Plan



National Infrastructure Protection Plan

2006



ATC 25

SEISMIC VULNERABILITY AND IMPACT OF DISRUPTION OF LIFELINES IN THE CONTERMINOUS UNITED STATES

APPLIED TECHNOLOGY COUNCIL



Funded by Federal Emergency Management Agency

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Power Systems, Transportation and Communications Lifeline Interdependencies

March 2006





NIST Technical Note 1476

Performance of Physical Structures in Hurricane Katrina and Hurricane Rita: A Reconnaissance Report



National Institute of Standards and Technology Technology Administration, U.S. Department of Commerce

AmericanLifelinesAlliance Apublic-private partmership to reduce risk to utility and transportation systems from natural

hazards and manmade threats

American Lifelines Alliance Workshop on Unified Data Collection

November 2007





Next Steps:

Immediate –

 Promote the use of existing standards and guidelines for new construction and upgrades

Longer Term –

- Develop consensus on level of hazard to be considered for use in new design or upgrades
- Develop and implement post-earthquake data collection/archive program



Expect the Unexpected