

# SUSTAINABLE DEVELOPMENT OF CRITICAL INFRASTRUCTURE

---

PROCEEDINGS OF THE 2014 INTERNATIONAL CONFERENCE ON  
SUSTAINABLE DEVELOPMENT OF CRITICAL INFRASTRUCTURE

---

May 16-18, 2014  
Shanghai, China

SPONSORED BY

The International Cooperation & Exchange Committee of the China Civil  
Engineering Society (CCES)  
The Council on Disaster Risk Management of the American Society of  
Civil Engineers (ASCE)

EDITED BY

Xila Liu  
A. H-S. Ang

ASCE Council on Disaster Risk Management  
Monograph No. 8

**ASCE** AMERICAN SOCIETY  
OF CIVIL ENGINEERS

This is a preview. [Click here to purchase the full publication.](#)

Published by American Society of Civil Engineers  
1801 Alexander Bell Drive  
Reston, Virginia, 20191-4382  
[www.asce.org/bookstore](http://www.asce.org/bookstore) | [ascelibrary.org](http://ascelibrary.org)

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. The information contained in these materials should not be used without first securing competent advice with respect to its suitability for any general or specific application. Anyone utilizing such 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 requested by sending an e-mail to [permissions@asce.org](mailto:permissions@asce.org) or by locating a title in ASCE's Civil Engineering Database (<http://cedb.asce.org>) or ASCE Library (<http://ascelibrary.org>) and using the "Permissions" link.

*Errata:* Errata, if any, can be found at <http://dx.doi.org/10.1061/9780784413470>

Copyright © 2014 by the American Society of Civil Engineers.  
All Rights Reserved.  
ISBN 978-0-7844-1347-0 (CD)  
ISBN 978-0-7844-7835-6 (E-book PDF)  
Manufactured in the United States of America.

# Preface

This volume contains the selected papers presented during the International Conference on *Sustainable Development of Critical Infrastructure* (IC-SDCI2014) held in Shanghai, China on 16-18 May 2014. All the papers were reviewed and approved by at least two reviewers. The Conference is the first event jointly sponsored by the China Civil Engineering Society (CCES) and the American Society of Civil Engineers (ASCE).

The publication of the Proceedings Volume is intended to widely promote and review the technologies necessary to support the engineering development of sustainable infrastructure systems in China and elsewhere. The Volume consisted of four keynote papers and 51 contributed papers on various topics dealing with these technologies, including namely the fields of impacts and adaptation to a climate change, reliability engineering and risk management, life-cycle performance and cost, and new developments of traditional construction materials such as reinforced concrete and steel. Specific applications of sustainable engineering systems include buildings, bridges, transportation systems, electric power systems, and nuclear power plants.

The technical and scientific programs of the Conference were organized under the leadership of the respective committees of the two sponsoring societies – namely, the Committee for International Cooperation & Exchange of the CCES and the Council on Disaster Risk Management (CDRM) of the ASCE. The Technical Council on Life-Cycle Engineering (TCLC) of the Institute of Structural Engineering (SEI) and other groups of ASCE also contributed to the technical program of the conference.

Financial supports for the Conference were provided by the Shanghai Jiao-Tong University and the construction industry of Shanghai; these financial supports are highly appreciated and gratefully acknowledged. The efforts of the faculty and staff of the University were essential in managing the organization and operation of the Conference; many thanks are due to their tireless assistance.

Finally, the efforts of all the authors and presenters of papers at the Conference are acknowledged with thanks and appreciation; the success of the Conference is a credit to the contributions of each and every author.

## ***Editors***

Xila Liu,  
Professor, Shanghai Jiao Tong University

and

A. H-S. Ang  
Research Professor, University of California, Irvine

# Conference Organization

## ***Honorary Chairs:***

Yun Chong Guo -- President, China Civil Engineering Society  
Randy Over -- President, American Society of Civil Engineers  
Jie Zhang -- President, Shanghai Jiao Tong University

## **Steering Committee**

## ***Conference Chairs***

Xila Liu, Shanghai Jiao Tong University  
Alfredo Ang (co-Chair), University of California, Irvine

## ***Members***

Erik Vanmarke -- Princeton University  
Dan Frangopol -- Lehigh University  
Bilal Ayyub -- University of Maryland  
Geoffrey Mills -- Institution of Civil Engineers (UK)  
Zhi Quan Jiang -- Shanghai Construction Group  
Wen Bo Zhou -- Shanghai Urban Construction Group  
Hua Zhang -- Shanghai Xian Dai Architectural Design (Group) Co., Ltd.  
Jin Ke Sun -- Shanghai Research Institute of Building Sciences (Group) Co., Ltd.  
Shao Pei Lin -- Shanghai Jiao Tong University

## **International Scientific Committee**

Alfredo Ang, Chair -- University of California, Irvine  
Xila Liu, co-Chair -- Shanghai Jiao Tong University  
Paul Chang -- Hong Kong University of Science and Technology  
Hitoshi Furuta -- Kansai University, Japan  
Yan Gang Zhao -- Kanagawa University 日本  
Sang-Hyo Kim -- Yonsei University, South Korea  
Hasan Kamal -- Kuwait Institute of Scientific Research, Kuwait  
Xilin Lv -- Tongji University  
Dong Ping Fan -- Tsinghua University  
Jia Ru Qian -- Tsinghua University  
Jian John Lu -- Shanghai Jiao Tong University  
Jin Cheng Zhao -- Shanghai Jiao Tong University  
Gang Wu -- Southeast University  
Chao Hui Chen -- Chongqing University  
Yun Gui Li -- China State Construction Engineering Corporation Ltd.  
Zhi Hua Shi -- China Academy of Building Research

Hen Shen Zhang -- China Society of Electric Engineering  
Hong Hui Ge -- Shanghai Nuclear Engineering Research & Design Institute  
Zong YuGao -- China Zhongtie -Major Bridge Reconnaissance & Design Institute Co.

### **Local Organizing Committee**

Hao Hu, Chair -- Shanghai Jiao Tong University  
Shui Long Shen, Vice Chair -- Shanghai Jiao Tong University  
Zhen Huang, Vice Chair -- Shanghai Jiao Tong University  
Feng Xu -- Shanghai Jiao Tong University  
Lulu Zhang -- Shanghai Jiao Tong University  
Fan Wu -- Shanghai Jiao Tong University  
Pei Yin Liu -- Shanghai Jiao Tong University Express  
Guang Liang Li -- Shanghai Jiao Tong University Express  
Ying Shi -- Shanghai Jiao Tong University  
Xue Ping Wu -- Shanghai Jiao Tong University  
Xiao Ning Zhao -- Tsinghua University

### **Co-Sponsors**

The IC-SDCI2014 is also co-sponsored by a number of Chinese and international organizations, including the following:

World Federation of Engineering Organizations (WFEO)  
Federation of Engineering Institutions of Asia and the Pacific (FEIAP)  
International Association for Bridge and Structural Engineering (IABSE)  
International Association for Structural Safety and Reliability (IASSAR)  
International Association for Bridge Maintenance and Safety (IABMAS)  
International Association for Life-Cycle Civil Engineering (IALCCE)  
China Association of Science and Technology (CAST)  
Chinese Academy of Engineering (CAE)  
American Association of Engineering Societies (AAES)  
American Concrete Institute (ACI)  
Institution of Civil Engineering (ICE)  
Institution of Structural Engineers (IStructE)  
Shanghai Construction Group (SCG)  
Shanghai Urban Construction Group (SUCG)  
Shanghai Xian Dai Architectural Design (Group) Co., Ltd.  
Shanghai Research Institute of Building Sciences (Group) Co., Ltd

# Table of Contents

## Keynote Papers

<b>Reliability-Based Design Criteria for Infrastructure Systems—A New Look</b>	<b>1</b>
Alfredo H-S. Ang	
<b>Practical Applications of Life-Cycle Considerations in Sustainable Development of Infrastructure</b>	<b>17</b>
Dan M. Frangopol, Mohamed Soliman, and You Dong	
<b>Multi-Hazard Risk Assessment of Civil Infrastructure Systems with a Focus on Long Linear Structures Such As Levees</b>	<b>37</b>
Erik Vanmarcke	
<b>Probabilistic Methodology for Quantifying Regional Risk Profiles from Sea Level Rise</b>	<b>57</b>
Bilal M. Ayyub	

## Workshop on Risk Management and Adaption to Climate Change

<b>Sustainability of Civil Infrastructure Systems: The Past, the Present, and the Way Forward</b>	<b>79</b>
Leslie Odartey Mills and Nii Attoh-Okine	
<b>Quantification and Valuations of Resilience for Emergency Management</b>	<b>91</b>
Bilal M. Ayyub	
<b>Risk Analysis of a Long-Distance Pipeline System in a Mountain Area Subjected to Multi-Hazards I: Risk of Rain-Caused Landslide</b>	<b>99</b>
Jinghua Huang, Zhaohui Chen, Peng Zhang, and Wenliang Fan	

**Risk Analysis of a Long-Distance Pipeline System in a Mountain Area  
Subjected to Multi-Hazards II: The Application** **108**

Zhaohui Chen, Jinghua Huang, Peng Zhang, and Wenliang Fan

**Reliability Assessment of RC Structures Subjected to Carbonation by  
Incorporating Spatial Variations** **115**

T. Hagino, M. Akiyama, and Dan M. Frangopol

# **Workshop on Practical Applications of Life-Cycle Considerations**

**Structural Upgrade Selection via Shortest-Path Algorithm Based on Life-  
Cycle Sustainability Metrics** **123**

Citlali Tapia and Jamie E. Padgett

**Concepts of Developing a Traffic Load Model for Multi-Span Cable Supported  
Bridges** **132**

Xin Ruan, Junyong Zhou, and Zhiyi Yin

**Incorporation of Concrete Rehabilitation Measures into Life-Cycle  
Maintenance** **141**

Harald Budelmann, Anne Wachsmann, and Alexander Holst

**Model of Compressive Strength Degradation of Concrete under Both Freeze-  
Thaw Cycles and Compressive Loads** **149**

Sijia Chen, Xiaobing Song, and Xila Liu

**Reliability Assessment of Bolting Systems for Steel Frames Connected to  
Reinforced Concrete Structures** **157**

Hasan Kamal, Jafarali Parol, Thamer Al-Yaqoub, Zafer Sakka, and Ahmad Yousif

# Construction Safety of Local and Overseas Projects

**Risk Management in China: Applying International Best Practices to Foreign-Invested Projects** 165

Geoffrey Mills

**Quantitative Solution of Overseas Project Risk Management by Knowledge Engineering** 174

Xu Feng, Shaopei Lin, Hu Hao, and Zhu Wei

**Software Integration of Safety Analysis of a Reinforced Concrete Structure Considering Temperature during Construction** 182

Kefeng Huang and Xila Liu

**Study on the Key Technology of Membrane Structure Design in the Shanghai Norwegian Pavilion** 190

Hao Song and Zefeng Bi

# Collapse Control of Critical Infrastructure during Strong Natural Disasters

**Quantitative Evaluation on Building Collapse-Induced Human Casualties for Performance-Based Earthquake Engineering** 197

Shuang Li, Yanjuan Zhang, Zhitao Du, Changhai Zhai, and Lili Xie

**A Unified Model of the Ultimate Capacity of RC Members with a Rectangular Section under Combined Actions** 204

Pu Wang, Huang Zhen, and Liang Sun

**Unified Failure Model of Reinforced Concrete Members Subjected to Hazard Loads I: Ductile Failure Analysis** 213

Xi Chen and Xila Liu



**Unified Failure Model of Reinforced Concrete Members Subjected to Hazard Loads II: Brittle Failure Analysis** 223

Xi Chen and Xila Liu

**Seismic Damage Assessment of Masonry Infilled Reinforced Concrete Structures** 230

Jia-Chao Zhang, Lei-Ming Zhang, Xi-La Liu, and Si-Jia Chen

**Numerical Analysis on Nonlinear Behavior of a Superimposed Wall under Quasi-Static Reversed Cyclic Loading** 238

Xun Chong, Junqi Huang, and Xianguo Ye

# Robustness of Critical Infrastructure under Terror Attacks

**The Rationality of the Geometric Topology of Cable Doms** 247

Danbing Long, Qin Zhang, and Xila Liu

**Topology-Based Quantitative Analysis of Structural Robustness** 255

Yang Gao and Xi-La Liu

**Topology-Based Robust Design of Structures** 263

Yang Gao and Xi-La Liu

**Flow Potential in Structures and Application in Analysis of Structural Vulnerability** 271

Ning Xu and Lei-Ming Zhang

**Robustness Analysis and Key Element Determination of Framed Structures** 280

Nan Xiao, Hai-Lei Zhan, and Hua-Peng Chen

# Transportation Systems for Regional Sustainable Development

**Numerical Simulations of Dynamic Responses of High-Speed Trains to Random Track Irregularities** 289

Mengyi Zhu, Xiaohui Cheng, and Lixin Miao

**Operational Evaluation of Vehicle Detection Systems at Rural Signalized Intersections** 298

Juan C. Pernia and Yolibeth Mejias

**A Metamodeling Technique for Exploring the Correlation between Mobility and Environmental Factors at Signalized Intersections** 306

Rui Guo and Yu Zhang

**An Optimization of Subway Vehicle Maintenance Using a Multi-Population Genetic Algorithm** 316

Di Zhang and Hao Hu

# Life-Cycle Engineering of Nuclear Power Systems

**A Failure Criterion for Steel-Concrete Composite Walls** 324

Xiaobing Song, Meng Chu, Honghui Ge, and Hailin Wang

**Research of the Wave Incoherence Effect of a Nuclear Power Plant on a Soft Soil Site** 332

Zhenkun Ding and Zufeng Xia

**Analysis of a Large Wide-Body Commercial Plane Impact on the CAP1400 Shield Building** 338

Shujian Cheng, Xiaowen Wang, Honghui Ge, and Zufeng Xia