

Proceedings of the 5th Asian-Pacific Symposium on  
Structural Reliability and its Applications

# Sustainable Civil Infrastructures

– Hazards, Risk, Uncertainty

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*Proceedings of the 5th Asian-Pacific Symposium on*  
**Structural Reliability and its Applications**  
**Sustainable Civil Infrastructures - Hazards, Risk, Uncertainty**

*Edited by*

**Phoon, K. K., Beer, M., Quek, S. T. and Pang, S. D.**

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## Preface

The Asian-Pacific Symposium on Structural Reliability and its Applications (APSSRA) is held every four years in between ICASP and ICOSSAR. The first APSSRA was held in Tokyo, Japan in November 1995; the second in Taipei, Taiwan in February 1999; the third in Seoul, Korea in August 2004; and the fourth in Hong Kong in June 2008. The fifth APSSRA is held in May 2012 in Singapore under the theme *Sustainable Civil Infrastructures – Hazards, Risk, Uncertainty*.

The Asia-Pacific region is witnessing unprecedented economic growth, concentration of population in mega-cities, and complexity and scale of infrastructural development. This sea change is taking place under looming global threats such as climate change and scarcity of resources. The development of innovative and sustainable solutions to improve life quality, while reducing hazard and risk and protecting both communities and the environment is the foremost challenge to civil engineers in the new millennium.

Risk management using structural reliability or other related concepts is integral to the above challenge not merely as a decision tool but also as a communication tool to engage non-engineering stakeholders in the public, government, and industry and between disciplines. We seek to encourage technical exchanges on advancing and closing knowledge gaps in risk and uncertainty with emphasis on sustainable development of civil infrastructures and mitigation of natural disasters. Every aspect of structural safety and reliability is covered. This includes both theoretical developments and practical applications for structures and systems in civil engineering and other related areas.

This proceedings contains 120 papers from 33 countries (Algeria, Australia, Austria, Belgium, Brazil, Bulgaria, Canada, Chile, China, Colombia, Czech Republic, Denmark, France, Germany, Hong Kong, India, Indonesia, Ireland, Italy, Japan, Republic of Korea, Mexico, Netherlands, Norway, Romania, Singapore, Switzerland, Taiwan, Turkey, Ukraine, United Kingdom, United States, and Vietnam) including 5 keynote papers and a significant number of papers contributed by experts in invited sessions. A special plenary session to honour the lifetime contributions of Professor Wilson Tang was organized in his memory in this Symposium.

This Symposium is organized by the Department of Civil and Environmental Engineering, National University of Singapore (NUS) in collaboration with the Institute for Risk and Uncertainty, University of Liverpool. It is supported by the Centre for Soft Ground Engineering (CSGE), NUS, Centre for Hazards Research (CHR), NUS, International Association for Structural Safety and Reliability (IASSAR), International Civil Engineering Risk and Reliability Association (CERRA), International Association for Bridge Maintenance and Safety (IABMAS), and International Association for Life-Cycle Civil Engineering (IALCCE). The organizers appreciate the support of these organizations, Lee Foundation, and our Gold Sponsor, Keppel Corporation. APSSRA2012 would not have been possible without their contributions and commitment.

The editors are grateful for the valuable services provided by the topic chairs and session organizers in the review process. The gracious contributions of the authors and the reviewers are acknowledged as well. The professional editing services rendered by the publisher, Research Publishing and its key members, Sankaran, Vimalanathan and Usha are acknowledged. Last but not least, Mr Kok Keong Cheah, Ms Yang

Chen and Ms Hui Leng Lim have managed our conference secretariat at our Faculty of Engineering Office of Professional Engineering & Executive Education very effectively and we are most appreciative of their service.

*Editors*

**Kok-Kwang Phoon**

**Michael Beer**

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#### Monte Carlo Methods and Engineering Applications

*Ivan Siu-Kui Au and Yu Wang*

#### Propagation of Uncertainties in Civil Engineering

*Jie Li and Jianbing Chen*

#### Recent Advancement in Geotechnical Reliability-based Design and Analysis

*Jianye Ching, Yu Wang and Jie-Ru Chen*

#### Design Optimization Techniques under Uncertainty

*Héctor A. Jensen, Michael Beer and Gerhart I. Schuëller*

#### Maintenance and Safety of Aging Infrastructure

*Dan M. Frangopol and Yiannis Tsompanakis*

#### Soft Computing Approach to Risk Management and Safety Problems

*Hitoshi Furuta, Isao Hayashi and Michiyuki Hirokane*

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## Honouring the Late Professor Wilson Tang

We received news of Professor Wilson Tang's passing with profound sadness during the preparation of APSSRA2012. Prof. Tang had a distinguished academic career in which he made significant contributions in the areas of safety and reliability analysis in civil engineering, particularly in geotechnical engineering. He is not only a pioneer in our research area, but he is well respected and loved by many colleagues and friends in our community for his humble and distinguished scholarship.

To honour his lifetime contributions, a Special Plenary Session consisting of invited presentations from his past students was organized by his close friend and colleague Professor Alfredo H.-S. Ang. The organizers are most appreciative of the efforts undertaken by Professor Ang. The organizers are also exceedingly proud to announce the establishment of the Wilson Tang Best Paper Award in honor of the late Professor Wilson Tang and his lifetime achievements in our community. This award will be presented for the first time in APSSRA2012. It is conferred to recognize the outstanding quality of a paper presented in APSSRA2012. The award will be presented during the symposium.

We are very grateful to Professor Tang's wife, Ms Bernadette Tang for her gracious permission to host the Special Plenary Session and to name the award after our pioneer, friend and colleague. We hope that these initiatives would keep Professor Wilson Tang and his achievements in our mind and encourage young colleagues to follow and emulate his research excellence and scholarship.