Geotechnical Safety and Risk IV

Editors: L.M. Zhang, Y. Wang, G. Wang and D.Q. Li

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Editors

L.M. Zhang
The Hong Kong University of Science and Technology, HKSAR

Y. Wang
City University of Hong Kong, HKSAR

G. Wang
The Hong Kong University of Science and Technology, HKSAR

D.Q. Li
Wuhan University, China

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Preface

The 4th International Symposium on Geotechnical Safety and Risk (4th ISGSR) was organised by the Hong Kong University of Science and Technology under the auspices of the Geotechnical Safety Network (GEOSNet; Chair, Daniel Straub; Co-chair Limin Zhang), Technical Committee TC304 on Engineering Practice of Risk Assessment and Management (Chair, K.K. Phoon) and Technical Committee TC205 on Safety and Serviceability in Geotechnical Design (Chair, Brian Simpson) of the International Society of Soil Mechanics and Geotechnical Engineering (ISSMGE). The Symposium was also supported by Hong Kong Geotechnical Society, the Geotechnical Division of the Hong Kong Institution of Engineers, Chinese Institution of Soil Mechanics and Geotechnical Engineering, the Engineering Risk and Insurance Branch of China Civil Engineering Society, and American Society of Civil Engineers—Hong Kong Section.

The 4th ISGSR was a continuation of a series of symposiums and workshops on geotechnical risk and reliability starting with LSD2000 in Melbourne, Australia, IWS2002 in Tokyo and Kamakura, Japan, LSD2003 in Cambridge, USA, Georisk2004 in Bangalore, India, Taipei2006 in Taipei, 1st ISGSR in Shanghai, China in 2007, 2nd ISGSR in Gifu, Japan in 2009 and 3rd ISGSR in Munich, Germany in 2011.

Safety, reliability, and risk assessment and management have attracted growing interests of the geotechnical community in recent years due to the frequent occurrences of natural and man-made disasters and the needs for safe and cost-effective design, construction and operations of infrastructures. At the same time there is an increasing expectation of the general public that requires the engineering community to provide quantitative information concerning risks posed by geotechnical hazards. The 4th ISGSR provided an excellent opportunity to better understand the geotechnical safety and risk management issues in engineering practices and research. The proceedings contain seven invited keynotes and 69 accepted papers from 28 countries and regions. Each accepted paper in the conference proceedings was subject to review by two peers. These papers cover six themes: (1) geotechnical uncertainty and variability, (2) geohazards such as landslides, earthquakes and climate changes, (3) reliability and risk analysis, (4) reliability-based design and limit-state design in geotechnical engineering, (5) risk assessment and management in geotechnical engineering and infrastructural projects, and (6) practical applications.

One of the highlights of this symposium was the 3rd Wilson Tang Lecture. The lecture was inaugurated during the 2nd ISGSR in Gifu to recognize and honor the significant contributions of the late Professor Wilson Tang, who was one of the founding researchers in geotechnical reliability and risk. The first lecture was given by Prof. T. H. Wu of the Ohio State University and the second lecture by Prof. Y. Honjo of Gifu University. The 3rd lecture was given by Prof. Suzanne Lacasse of Norwegian Geotechnical Institute during the 4th ISGSR.

The credit for the proceedings goes to the authors and reviewers. The publication of the proceedings was financially supported by the National Basic Research Program of China (Grant No. 2011CB013500) and the National Natural Science Foundation of China's Oversea Collaborative Research Program (Grant No. 51129902).

Limin Zhang
Chairman of the Regional Organising Committee
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1 *Wilson Tang lecture*

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An homage to Wilson Tang: Reliability and risk in geotechnical practice—how Wilson led the way

S. Lacasse, K. Høeg, Z.Q. Liu & F. Nadim
Norwegian Geotechnical Institute, Oslo, Norway

ABSTRACT: The paper is in homage to Professor Wilson Tang for his inspiration to fellow engineers in the area of geotechnical engineering. The role of statistics, probability and reliability in geotechnical engineering is first outlined. Examples of solutions based on Wilson Tang's pioneering work are presented: uncertainties in soil parameters; Bayesian updating applications; reliability of tailings dam; model uncertainty and calibration of safety factor. Two aspects of special interest to Wilson Tang are also briefly discussed: improving the cost-effectiveness of site investigations and the reliability of offshore structures.

1 INTRODUCTION

This paper is in homage to Professor Wilson Tang (1943–2012) for his inspiration to fellow engineers to pursue his pioneering work in the application of reliability and risk in geotechnical engineering. The paper illustrates how the work initiated by Wilson Tang led the way to further developments by his colleagues, research partners, friends and practitioners in the geotechnical profession. Case studies based on Wilson Tang's learnings are provided for several geotechnical applications.

Wilson Tang's work covered a wide range of expertise areas within statistics, probability and reliability. These include: characterization of soil properties and random field models, reliability methods, structural reliability-based design, Bayesian updating and decision-making. Wilson applied reliability concepts to, for example, site investigation and geotechnical anomaly characterization, the analysis of slopes and offshore structures, earthquake hazard, the analysis of foundation solutions, model uncertainty and the calibration of safety factors. Wilson's work also covered the reliability of landfill systems, accident hazard analysis and prediction, and road network reliability.

Wilson Tang was a graduate student of the second author, post-doctoral fellow at NGI, the external doctoral examiner for the third author, and an inspiration and friend to all four authors. This is only a random cross-section of three generations of engineers at NGI. His radius of influence is so much wider, as he touched the lives of many in so many ways.

Examples of Wilson Tang's lasting influence are the invited papers for the 2013 ISGSR. The keynote speakers come from three continents, have very different backgrounds and different career profiles and are at different stages in their engineering profession. Yet, each of these recognized keynote lecturers has been influenced by Wilson's work, as witnessed by the list in Table 1.

After introductory comments on the role of statistics, probability and reliability in geotechnical engineering, the paper emphasizes four topics with solutions in large part developed thanks to the foundations laid by Wilson Tang:

- Uncertainties in soil parameters in practice.
- New applications for Bayesian updating.
- Reliability of containment facility.
- Model uncertainty and calibration of safety factors.

Table 1. Keynote contributions at ISGSR 2013.

Author	Title of keynote paper
Gilbert et al. (2013)	Advances in geotechnical risk and reliability for offshore applications
Griffiths et al. (2013)	Homogenization of geomaterials using the random finite element method
Huang et al. (2013)	Selecting optimal probability models for geotechnical reliability analysis
Juang et al. (2013)	Robust design of geotechnical barriers—A new design perspective
van Staveren (2013)	Integrated geo risk management: crossing boundaries
Wong (2013)	Is landslide risk quantifiable and manageable?

Furthermore, two additional aspects of special interest to Wilson Tang are briefly discussed: the use of probabilistic concepts to improve the cost-effectiveness of site investigations and to estimate the reliability of offshore structures.

2 ROLE OF STATISTICS, PROBABILITY AND RELIABILITY IN GEOTECHNICAL ENGINEERING

Wilson Tang and his co-author A. H-S Ang firmly believed that the best and most effective way for engineers to learn the concepts of probability, statistics and risk was through applications of the principles to engineering problems. It was important for them to be able to show the usefulness of the method in physically meaningful terms.

The motivation for probabilistic and statistical decision theory is multi-fold: uncertainties are unavoidable, and they need to be considered and reduced where possible; the need for a systematic development of design criteria for engineering designs; and quantitative risk assessment offers a logical framework for decision-making and documentation of the steps towards the decisions. In light of uncertainties, the role of probability and statistics ranges from the description of the basic information to the development of formulations as basis for design and decision-making (Ang & Tang 2007). Especially in geotechnical engineering, our knowledge is imperfect.

As part of design and decision-making under uncertainty (Høeg 1996), the properties of inherently inhomogeneous and highly variable soil materials must be considered. Natural deposits typically have irregular layers of clay, silt, sand, gravel or a combination thereof. The soil properties that affect strength and compressibility often have a wide range of variation. The information comes from the local geology, and limited soil or rock sampling and limited coverage of the area of concern with *in situ* tests.

The calculated bearing capacity (stability) can vary widely according to the analysis parameters and the calculation method selected. The calculation will therefore involve some possibility of overestimating the actual resistance provided by the soil, or leading to unnecessarily high costs due to overly conservative design. There will therefore always be a finite probability that the forces on a structure founded on or in soil or rock can cause damage, or the total collapse, of the structure.

Statistics, probability, reliability and the decisions made on the basis of these concepts offer remarkable tools that can quantify the trade-off between cost and tolerable probability of non-performance (failure) and risk (sentence slightly modified from Ang & Tang 2007). Such considerations, and as exemplified by Wilson Tang's long list of publications, can be extended to the entire chain of geotechnical design steps, from site investigation and soil testing, selection of design parameters to design calculations, reliability of a design method and selection of required safety factor(s).

The examples presented in this paper illustrate the role of statistics, probability and reliability in geo-engineering.

In the books "Probability concepts in engineering, planning and design" (Volume I and II 1975; 1984) and "Probability concepts in engineering—Emphasis on applications to civil and environmental engineering" (2nd ed. of Volume I–2007), Ang and Tang published two of the first books that made the probability concepts easily accessible to geotechnical engineers.

From an engineering standpoint, the Ang and Tang books, together with Benjamin & Cornell (1970) were instrumental in pointing the way for most users, including the authors of this paper. As a doctoral student at Stanford University, the young Wilson Tang greatly benefitted from the lectures and discussion with Professor Jack Benjamin.

Later books, especially Baecher & Christian (2003) and Fenton & Griffiths (2008) are of special relevance for geotechnical engineers. Vick (2002) and Jordaan (2008), for example, published books on decisions under uncertainty and continue the legacy of Wilson Tang. Yet, the first Ang and Tang's books have the far-reaching influence of being the pioneers for geotechnical engineers.

3 UNCERTAINTIES IN SOIL PARAMETERS IN PRACTICE

The terms 'aleatory' uncertainties (those associated with natural randomness) and 'epistemic' uncertainties (those associated with uncertainties in prediction and estimation) are known today. The terms 'aleatory' and 'epistemic' were first used by Hacking (1975) and Cornell, C.A (1982, Personal comm., Pau, France).

The importance of quantifying the variability in geotechnical design parameters is not adequately recognized in practice. Quantifying variability is a positive contribution as its consistent modelling and utilization lead, with limited additional effort, to more rational and economic designs. The modelling of soil variability belongs to one of two categories: (a) geostatistics, focusing on the interpolation of available data to estimate other values at the same location; and (b) reliability-based engineering, focusing on characterization for reliability/risk assessment.

A soil variability analysis can include three steps, each with increasing level of complexity: