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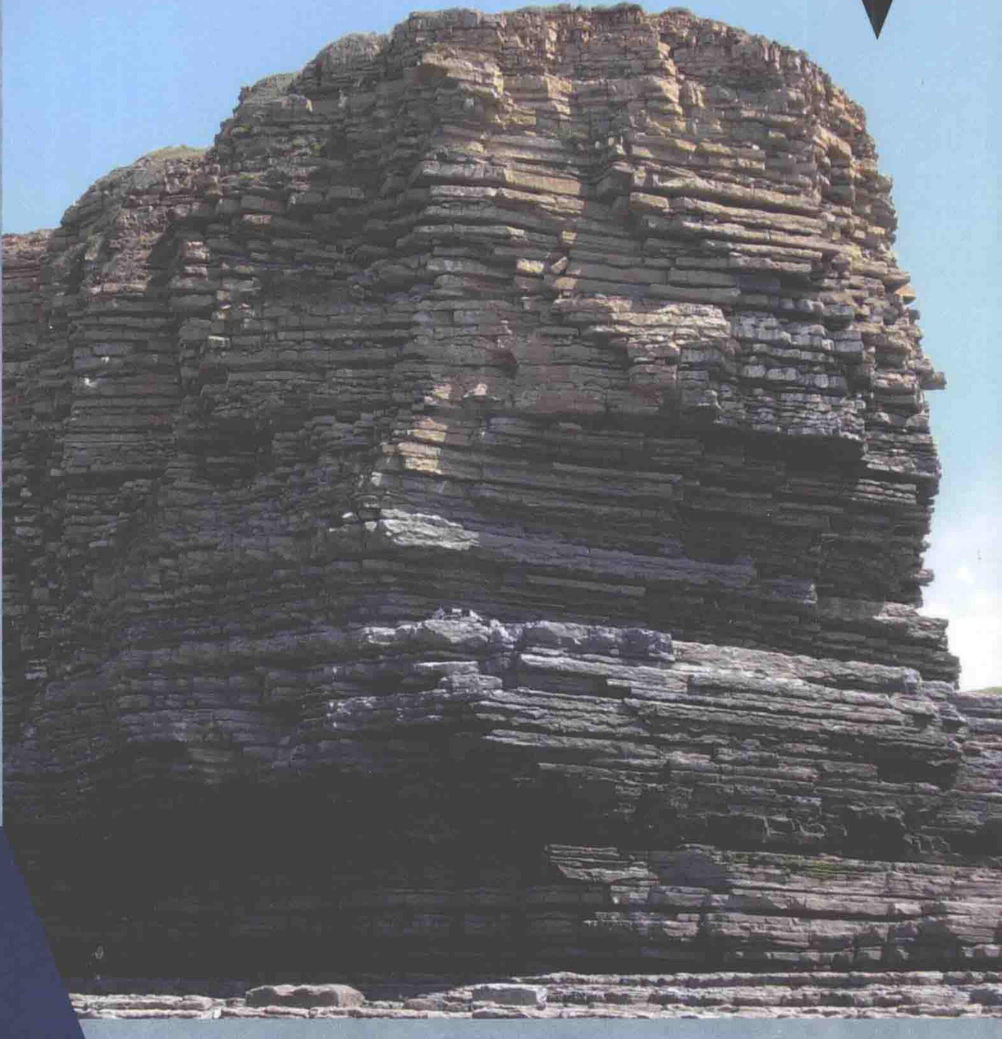

Rock Engineering Risk

John A. Hudson
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A BALKEMA BOOK

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The photograph on the front cover is of a limestone and mudstone rock mass in South Wales, UK, as an example of the discontinuous, inhomogeneous and anisotropic nature of most rock masses.

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Preface

The purpose of this book is to describe the subject of risk as it relates to the design and construction of engineering projects located on or within rock masses. Traditionally, such projects include facilities such as building foundations, dams, slopes, tunnels, caverns and mines; but, more recently, other increasingly complex rock engineering projects are being developed, constructed and operated, such as geothermal energy, radioactive waste disposal, CO_2 storage and hydraulic fracturing for shale gas. In all these projects, there are risks involved in the separate aspects of site investigation, modelling, design and construction—together with their cumulative effect on the operation of the whole project.

Our previous 2011 book, "Rock Engineering Design", published by CRC Press/Balkema (Taylor & Francis Group), was also concerned with the design of projects constructed on or in rock masses, i.e., slopes, dams, hydroelectric schemes, mines, and repositories for radioactive waste disposal. That book covered rock engineering design methodologies, associated flowcharts, the information required, technical auditing of design, a rock slope case example, an underground hydroelectric powerhouse case example, Protocol Sheets for auditing rock engineering design, and examples of the use of Protocol Sheets. This new book, "Rock Engineering Risk", covers the related and important subject of risk using the Frontispiece flowchart in which the risks are considered in terms of the uncertainties associated with 'before construction' and 'during construction' factors.

The emphasis in the book is on the physical aspects of these subjects, the rock mechanics and the rock engineering, rather than the financial aspects, although of course there are financial ramifications associated with the mitigation of the physical risks. Chapters 1–5 provide information on the subject of risk and the approaches to reducing risk, especially in the context of design and construction for underground rock engineering, although the general principles apply also to surface rock engineering. Chapters 6 and 7 contain two detailed, major case examples from China relating to long tunnels at great depth and a hydropower cavern complex. These two Chapters contain a wealth of information relating to the practical risk reduction methods described in the earlier chapters and the experiences of their application during both tunnelling and cavern construction.

Both our previously published book on 'rock engineering design' and this book on 'rock engineering risk' are outputs from the International Society for Rock Mechanics (ISRM) Commission on Design Methodology. The earlier 'rock engineering design' book was generated when John A. Hudson was President of the ISRM (2007–2011), and this new book on 'rock engineering risk' was generated while Xia-Ting Feng was President of the ISRM (2011–2015).

We are pleased to report that this book is the first in the newly established CRC Press/Balkema ISRM Book Series.

John A. Hudson and Xia-Ting Feng,
2015

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Acknowledgements

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We are especially grateful to Professor E.T. Brown of Golder Associates in Australia who originally recommended that the ISRM Design Methodology Commission should focus on 'rock engineering risk' in the 2011–2015 ISRM Presidential tenure period—following the earlier 2007–2011 research on 'rock engineering design'. The risk subject certainly required attention and we hope that now, four years later, the Commission has indeed made a worthwhile contribution through the publication of this book.

Thus, the ISRM Design Methodology Commission was active in the period 2011–2015 and the authors, as respectively Commission President and Commission Co-President, are significantly indebted to the ISRM Commission Members listed below who actively took part in discussions held in association with ISRM symposia, made many suggestions and provided reference material.

> *Dr Conrad Felice, Mr Erik Johansson, Prof. Frederic Pellet, Prof. Wulf Schubert, Prof. Alexandros Sofianos, Prof. Ove Stephansson, Prof. Leslie G. Tham, Dr Antonio Samaniego, Dr Mostafa Sharifzadeh, Prof. Resat Ulusay, Mr Lauri Uotinen, Dr Philippe Vaskou, Dr Christophe Vibert, Dr Thierry You, Dr Yingxin Zhou.*

The authors are additionally grateful to Professor Qian Qihu, Academician of the Chinese Academy of Engineering and President of the Chinese Society for Rock Mechanics and Engineering for his continuing support of the ISRM Design Methodology Commission's work.

Also, the authors are indebted to Dr Chin-Fu Tsang (former DECOVALEX Project Chairman) and Dr Lanru Jing (DECOVALEX Project Secretary) for their assistance in providing some of the DECOVALEX historical material in Chapter 5. The authors appreciate and thank the DECOVALEX2015 Funding Organisations for their financial and technical support of the DECOVALEX project work described in that Chapter. The statements made in this book are, however, solely those of the authors and do not necessarily reflect those of the DECOVALEX Funding Organisations.

In addition, we thank the following personnel who contributed to the content of Chapters 6 and 7 describing the major tunnel and hydropower case examples; their help has significantly enhanced the content and value of the book. Dr Qiu Shili and Dr Zhang Yongjie wrote the first drafts of Chapters 6 and 7, respectively, and Dr Qiu Shili also assisted with some of the diagram preparation. Professor Jiang Quan provided ideas and considerable information relating to risk assessment of underground cavern groups. Professors Zhang Chunsheng, Hou Jing and Chen Xiangrong were involved with the geological conditions and design information for the Jinping II Project. Professor Chen Bingrui, Dr Xiao Yaxun and Mr Feng Guangliang took part in the rockburst monitoring and warning system in the headrace tunnels and water drainage tunnel at the Jinping II Project site, and Professors Wu Shiyong, Wang Jimin and Zeng Xionghui also provided support for that aspect of the work.

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Lastly, we express our profound thanks to Carol Hudson for her meticulous checking of all the details of not only the original manuscript, but also both the initial and final proofs of the book. We may not have eliminated all the errors but, through Carol's help, there are far fewer.

About the authors

John A. Hudson and Xia-Ting Feng at an International Society for Rock Mechanics (ISRM) Task Force meeting of the Commission on Design Methodology held at the Institute of Rock and Soil Mechanics, Chinese Academy of Sciences, Wuhan, China.

ISRM President 2007–2011: John A. Hudson
ISRM President 2011–2015: Xia-Ting Feng

PROFESSOR JOHN A. HUDSON

John A. Hudson graduated from the Heriot-Watt University, UK, and obtained his PhD at the University of Minnesota, USA. He has spent his professional career in consulting, research, teaching and publishing in engineering rock mechanics, and was awarded the DSc. degree by the Heriot-Watt University for his contributions to the subject. He has authored many scientific papers and books, and was the editor of the 1993 five-volume "Comprehensive Rock Engineering" compendium, and from 1983–2006 editor of the International Journal of Rock Mechanics and Mining Sciences. Since 1983, he has been affiliated with Imperial College London as Reader, Professor and now Emeritus Professor. In 1998, he became a Fellow of the UK Royal Academy of Engineering and was President of the International Society for Rock Mechanics (ISRM) for the period 2007–2011. In 2015, the 7th ISRM Müller Award was conferred on Professor Hudson in recognition of "an outstanding career that combines theoretical and applied rock engineering with a profound understanding of the basic sciences of geology and mechanics".

PROFESSOR XIA-TING FENG

Xia-Ting Feng graduated in 1986 from the Northeast University of Technology and obtained his PhD in 1992 at the Northeastern University, China. He was then appointed and acted as Lecturer, Associate Professor and Professor at the same university. In 1998, he was admitted by the Hundred Talents Programme to the Chinese Academy of Sciences (CAS). Subsequently, he permanently joined CAS's Institute of Rock and Soil Mechanics at Wuhan, China. In 2003, he obtained the support of the China National Funds for Distinguished Young Scientists; in 2010, he became a Chair Professor of the Cheung Kong Scholars' Programme, Ministry of Education, China; and, in 2009, he was elected as President of the International Society for Rock Mechanics for the period 2011–2015. He is currently Director of the State Key Laboratory of Geomechanics and Geotechnical Engineering in Wuhan. Additionally, in 2012, Professor Feng became the Co-President of the Chinese Society for Rock Mechanics and Engineering. He has made original contributions to the subject of 'intelligent rock mechanics' and his methods have been applied to large rock engineering projects in China and other countries.

Contents

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