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Proceedings of International Geotechnics Symposium cum International Meeting of CSRME 14th Biennial National Congress, 14-17 December 2016, Hong Kong, China

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Organizers

Chinese Society for Rock Mechanics and Engineering (CSRME)

The University of Hong Kong (HKU)

Proceedings of International Geotechnics Symposium cum International Meeting of CSRME 14th Biennial National Congress

14-17 December 2016, Hong Kong, China

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Preface

With great pleasure, we are expecting the CSRME 14th Biennial National Congress and the International Geotechnics Symposium cum International Meeting of CSRME 14th Biennial National Congress to be held from December 11 to 15 in the city of Guangzhou and from December 14 to 17 in the main campus of The University of Hong Kong (HKU), respectively.

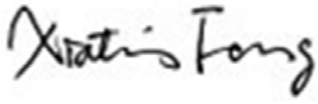
CSRME stands for the Chinese Society for Rock Mechanics and Engineering. CSRME was established in 1985 and aims at promoting activities related to the studies of the physical and mechanical behavior of rocks and soils for better and safer geotechnical design and construction. At present, CSRME has more than 10,000 individual members and has organized more than 400 symposiums or conferences including the 12th Congress of International Society for Rock Mechanics.

In recent years, many disastrous rock and soil failures have occurred around the world including China. These disasters have revealed various issues and much room for improvement in conventional theories of geo-mechanics and geo-sciences, as well as techniques in geo-engineering. Therefore, the CSRME has decided to extend the 14th Biennial National Congress to the international geotechnical and geoscience communities. HKU is chosen as the co-organizer and venue of this International Symposium and Meeting, as it presents over one hundred years of excellence in teaching and research in Hong Kong and Hong Kong has acted as a bridge between Mainland China and the international communities for many decades.

The theme of the International Symposium and Meeting is the Causes, Mechanisms and Prevention of Disastrous Soil & Rock Failures. Under this theme, we have invited eleven world-renowned experts to deliver keynote lectures. Based on the submitted abstracts, 22 authors are invited to deliver theme lectures and 44 authors are invited to give oral presentations. These presentations will cover four specific subjects including a) Rock Cavern and Tunnel Engineering, b) Slope Stability and Landslides, c) Geo-environmental Mechanics and Engineering, and d) Mechanism of Soil and Rock Failures. Their latest research and developments will be presented, discussed and exchanged in seven plenary sessions and five parallel sessions. In particular, one plenary session is specially organized in Celebration of the 70th Birthday of Professor Maurice B. Dusseault by his students, and one parallel session is designated for the Best Paper Award Competition for Young Researchers.

This International Symposium and Meeting has received generous financial supports from both the State Key Laboratory of Geomechanics and Geotechnical Engineering of the Chinese Academy of Sciences' Institute of Rock and Soil Mechanics and the China Three Gorges University. Also we would like to acknowledge the in-kind supports from both the Geotechnical Division of Hong Kong Institution of Engineers and The Hong Kong Geotechnical Society, as well as professional supports from China Harbour Engineering Co., Ltd. for arranging the technical visits in Hong Kong.

We are looking forward to the fruitful discussion and exchange of the new ideas and successful experiences among the delegates and speakers from more than 73 organizations and 42 cities in Canada, China, Germany, Japan, Singapore, UK, and USA.



Professor Xiating Feng
President of CSRME

Professor Zhong-qi Quentin Yue
Chairman of Executive Organizing Committee

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The University of Hong Kong (HKU)

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China Three Gorges University

Geotechnical Division, Hong Kong Institution of Engineers

The Hong Kong Geotechnical Society

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Prof. X.Q. Zhong	Guangdong Foundation Engineering Group Co., Ltd.

Secretariat

Ms. Bridget Lam and Ms. Ruby Kwok

Summary of Scientific Programme

Venue: Graduate House (GH), Main Campus, The University of Hong Kong

Dec. 14, 2016	**Wednesday**	
13:00-18:00	On-site Registration	Foyer, GH
17:00-18:00	Cocktail Reception	Foyer, GH

Dec. 15, 2016	**Thursday**	
8:15-17:00	On-site Registration	Foyer, GH
8:45-9:15	Opening Ceremony	Wang Gungwu Theatre, GH
9:15-10:15	Plenary Session 1	Wang Gungwu Theatre, GH
10:15-10:25	Group Photo	All Delegates at Staircase Space outside GH
10:25-10:40	Coffee-Tea Break	Foyer, GH
10:40-12:10	Plenary Session 2	Wang Gungwu Theatre, GH
12:10-13:30	Lunch	Lunch Box at Foyer, GH
13:30-16:00	Plenary Session 3	Wang Gungwu Theatre, GH
16:00-16:20	Coffee-Tea Break	Foyer, GH
16:20-18:10	Parallel Session 1	Wang Gungwu Theatre, GH
	Parallel Session 2	Seminar Room P5-03, GH
	Parallel Session 3	Seminar Room P5-01, GH
19:00-21:30	Banquet	Victoria Harbour Restaurant, Westwood Mall

Dec. 16, 2016	**Friday**	
8:30-17:00	On-site Registration	Foyer, GH
9:00-10:30	Plenary Session 4	Wang Gungwu Theatre, GH
10:30-10:45	Coffee-Tea Break	Foyer, GH
10:45-12:15	Plenary Session 5	Wang Gungwu Theatre, GH
12:15-13:30	Lunch	Lunch Box at Foyer, GH
13:30-15:00	Plenary Session 6	Wang Gungwu Theatre, GH
15:00-16:00	Plenary Session 7	Wang Gungwu Theatre, GH
16:00-16:10	Coffee-Tea Break	Foyer, GH
16:10-17:30	Parallel Session 4	Seminar Room P5-01, GH
	Parallel Session 5	Wang Gungwu Theatre, GH
17:30-18:00	Closing Ceremony	Wang Gungwu Theatre, GH
19:00-21:30	Dinner	Fulum Restaurant, 455-485 Queen's Road West

Dec. 17, 2016	**Saturday**	
9:00-12:00	Technical Site Visit 1	Hong Kong-Zhuhai-Macao Bridge Project
12:00-14:00	Lunch	Tung Chung
14:00-17:00	Technical Site Visit 2	Po Lin Monastery and Country Park

Detailed Scientific Programme

December 14, 2016 Wednesday

13:00-18:00	On-site registration	Foyer, Graduate House (GH)
17:00-18:00	Cocktail reception	Foyer, Graduate House (GH)

December 15, 2016 Thursday

8:15-17:00	On-site registration	Foyer, Graduate House (GH)

Opening Ceremony **Wang Gungwu Theatre, GH**

Chairman: Zhong-qi Quentin Yue

8:45-8:55 Welcome Speech - Professor Norman Tien, Dean of Faculty of Engineering, HKU

8:55-9:05 Welcome Speech - Professor Qihu Qian, President of Chinese Society of Rock Mechanics and Engineering

9:05-9:15 Opening Speech – Professor C.F. Lee, Chancellor of Chu Hai College of Higher Education

Plenary Session 1 – Rock Cavern and Tunnel Engineering 1 **Wang Gungwu Theatre, GH**

Chairman: C. F. Lee

9:15-9:45 Construction and Operation of Tunnels in the Urban Environment – A Risk Based Approach - Herbert H. Einstein (Keynote Lecture 1)

9:45-10:15 Lessons Learned from Design of Surrounding Supports in Rock Mass with High In-situ Stresses – Qihu Qian (Keynote Lecture 2)

10:15-10:25 Group Photo — Staircase outside GH

10:25-10:40 Coffee-Tea Break — Foyer, Graduate House (GH)

Plenary Session 2 – Rock Cavern and Tunnel Engineering 2 **Wang Gungwu Theatre, GH**

Chairman: A. P. S. Selvadurai

10:40-11:10 Rock Mass Behaviour during Excavation of China Jinping Underground Laboratories with Overburden of 2400 m – Xia-ting Feng (Keynote Lecture 3)

11:10-11:40 Geo-disaster Prediction with Double-blocks Mechanics Theory Based on Newton Force Measurement – Man-chao He (Keynote Lecture 4)

11:40-12:10 Cavern and Tunnel Failures due to Adverse Structural Geology and Inadequate Support Designs – Nick Barton (Keynote Lecture 5)

12:10-13:30 Lunch — Lunch Box at Foyer, Graduate House (GH)

Plenary Session 3 – Geo-Environmental Mechanics and Engineering 1 **Wang Gungwu Theatre, GH**

Chairman: Maurice B. Dusseault

13:30-14:00 Thermo-Poromechanics of Geologic Media – A. P. S. Selvadurai (Keynote Lecture 6)

14:00-14:30 Deep Energy Geomechanics: Extraction, Storage, Disposal – Maurice B. Dusseault (Keynote Lecture 7)

14:30-14:45 Static Liquefaction and Flow Failure of Sand: Several New Findings – Jun Yang (Theme Lecture 1)

14:45-15:00 Blasting Vibration Analyses of Millisecond Blasting Model Experiment with Multicircle Vertical Blastholes – Qin-yong Ma (Theme Lecture 2)

15:00-15:15 Conceptual Model of Enhanced Geothermal System Based on Excavation Technology (EGS-E) – Chun-an Tang (Theme Lecture 3)

15:15-15:30 An Overview of Pavement Forward and Inverse Analyses – Er-nian Pan (Theme Lecture 4)

15:30-15:45 Material Design: Perspectives and Status for MGI – Lin-bing Wang (Theme Lecture 5)

15:45-16:00 Explanation of Thermo-Hydraulic-Mechanical Behavior of Geomaterials in So-Called Isothermal Heating Test – Feng Zhang (Theme Lecture 6)

16:00-16:20 Coffee-Tea Break Foyer, Graduate House (GH)

Parallel Session 1 – Rock Cavern and Tunnel Engineering 3 Wang Gungwu Theatre, GH
Chairman: Ji-dong Zhao

16:20-16:30 Long-term Performance of Large Longyou Caverns Manually Carved in Argillaceous Siltstone Ground – Z. Q. Yue (Paper 1)

16:30-16:40 Characteristics on Rock Fractures Induced by Different Excavation Methods of Deep Tunnels – S. J. Li (Paper 2)

16:40-16:50 Impact Analysis of Tunnel Cross Section Shape on Tunnel Temperature Field Calculation – Y. H. Zeng (Paper 3)

16:50-17:00 Research on Deformation Rules of Surrounding Rock of the Shallowly-Buried Water Rich Loess Tunnel Influenced by Freezing-Thawing Circumstance – G. S. Yang (Paper 4)

17:00-17:10 Investigation of the Joint Yielding Mode of Segmental Tunnel Lining – X. P. Dong (Paper 5)

17:10-17:20 Detection and Analysis of Harmful Gas Emission in Hongyanxi Tunnel – H. L. Fu (Paper 6)

17:20-17:30 Geological Structure and Mineralization Mechanism of Shale Gas in the Red Rock Creek Tunnel – H. L. Fu (Paper 7)

17:30-17:40 Improved Procedure for Determining Reaction Curve of Anchoring and Shotcreting Support in Circular Tunnel – F. X. Sun (Paper 8)

17:40-17:50 Reliability-Based Design for Rock Tunnel Stability Using Inverse-Reliability Approach – X. Li (Paper 9)

17:50-18:00 Effects of Defect Doping on Kaolinite (001) Surface with H_2O Adsorption – J. Zhao (Paper 10)

18:00-18:10 Three-Dimensional Dynamic Analysis of Quay Walls Based on PZC Mode C. Jing – (Paper 11)

Parallel Session 2 – Mechanism of Soil and Rock Failures 1 Seminar Room P5-03, GH
Chairman: Li-min Zhang

16:20-16:30 Study on Mechanical Features of Brazilian Splitting Fatigue Tests of Salt Rock – W. C. Wang (Paper 12)

16:30-16:40 Method for Describing Mesostructure of Heterogeneous Rock Material Based on Spatial Correlation Character – W. M. Huang (Paper 13)

16:40-16:50 Mode I-II Compression-shear Fracture Criterion for Non-contacting Crack of Rock-like Brittle Materials – L. Z. Wu (Paper 14)

16:50-17:00 Sand Grain Crushing under Multi-axial Loading Conditions – F. Zhu (Paper 15)

17:00-17:10 Experimental Study on Dynamic Deformation of Unsaturated Granite Residual Soils – F. C. Zhu (Paper 16)

17:10-17:20 Soil Responses under the Principal Stress Rotation – Y. M. Yang (Paper 17)

17:20-17:30 Multiscale Analysis of Asphalt Binder Fatigue Cracking – L. B. Wang (Paper 18)

17:30-17:40 Numerical Study on THM Processes of EBS Experiment – P. Z. Pan (Paper 19)

17:40-17:50 Mechanism and Control Technology of Panel Roadway Floor Heave – C. K. Liu (Paper 20)

17:50-18:00 Cushion Pad of Reducing Blasting Vibration – Starting New Era of Decreasing Disaster in Civil Engineering – X. D. Meng (Paper 21)

18:00-18:10 Spatial-temporal Pattern of Socio-economic Vulnerability to Geohazards in Bailong River Basin, China – D. X. Yue (Paper 22)

Parallel Session 3 – Best Paper Award Competition for Young Researchers Seminar Room P5-01, GH
Chairmen: Louis Wong & Andy Leung

16:20-16:30 Experimental Study on Zonal Disintegration Phenomenon in Deep Rock Mass under Blasting Excavation – P. Yuan (Paper 23)

16:30-16:40 Study on the Block-Water Capability of Main Roof Structures of Steep Coal Seams with Fully-Mechanized Caving – Z.Q. Yu (Paper 24)

16:40-16:50 Vulnerability Assessment Model for Hazard Bearing Body Closed to Landslides Considering Run-out Process of Sliding Body – H.Q. Yang (Paper 25)

16:50-17:00 Synthetic Water Repellent Soils and Slope Engineering – S. Zheng (Paper 26)

17:00-17:10 Effect of Micro-gas Inclusions on Abnormally Delayed Mechanical Behaviour of Intact Rocks after Excavation – Y.L. Ding (Paper 27)

17:10-17:20 Experimental and Numerical Study of Depositional Mechanism of Mudflows – L. Jing (Paper 28)

17:20-17:30 Shakedown Analysis of Lined Rock Cavern for Compressed Air Energy Storage – J. Wang (Paper 29)

17:30-17:40 Dynamic Loading of Carrara Marble in a Heated State – Z. Li (Paper 30)

17:40-17:50 Inverse Reliability-Based Analysis and Design in Slope Engineering – A. Farina (Paper 31)

19:00-21:30 Banquet Victoria Harbour Restaurant, Westwood Mall, near HKU Main Campus at MTR HKU Station Exit C2

December 16 Friday

8:30 – 17:00 On-site registration Foyer, Graduate House (GH)

Plenary Session 4 – Slope Stability and Landslides 1 Wang Gungwu Theatre, GH
Chairman: Xia-ting Feng

9:00-9:30 Urban Landslide Risk Management amid the Challenge of Climate Change – H. N. Wong (Keynote Lecture 8)

9:30-10:00 Unloading Rock Mass Mechanics – Jian-lin Li (Keynote 9)

10:00-10:30 Stability Analysis on Natural or Artificial Slopes under Earthquake Loading Based on Non-Linear Material Models – Theodoros Triantafyllidis (Keynote 10)

10:30-10:45 Coffee-Tea Break — Foyer, Graduate House (GH)

Plenary Session 5 – Slope Stability and Landslides 2 — **Wang Gungwu Theatre, GH**
Chairman: Jun Yang

10:45-11:15 Contact Theory – The Foundation of Discontinuous Computations – Gen-hua Shi (Keynote Lecture 11)

11:15-11:30 Cause and Mechanism of Fatal Zhenxiong Landslide of January 11, 2013 – Zhong-qi Quentin Yue (Theme Lecture 7)

11:30-11:45 A Critical Analysis and Stabilization of Nipigon River Landslide in Ontario, Canada – Jian Deng (Theme Lecture 8)

11:45-12:00 Effectiveness of Debris Flow Mitigation Strategies in Mountainous Region – Xing-min Meng (Theme Lecture 9)

12:00-12:15 Mechanism and New Stability Analyses of Progressive Failure of the Thrust-type Landslide – Ying-fa Lu (Theme Lecture 10)

12:15-13:30 Lunch — Lunch Box at Foyer, Graduate House (GH)

Plenary Session 6 – Mechanism of Rock and Soil Failures 2 — **Wang Gungwu Theatre, GH**
Chairman: Feng Zhang

13:30-13:45 Numerical Analysis of Failure Processes in Soil-Rock Mixtures Using Computed Tomography and 3D Particle Flow Code Models – Yang Ju (Theme Lecture 11)

13:45-14:00 Fluid Transport in Extensively Fractured Rocks – A. Patrick S. Selvadurai (Theme Lecture 12)

14:00-14:15 Replicating Brittle and Hard Rocks Using 3D Printing with Applications to Rock Dynamics and Crack Propagation – Jian-bo Zhu (Theme Lecture 13)

14:15-14:30 Analysis of Crack Problems in Graded Halfspace Subject to Complex Loading – Hong-tian Xiao (Theme Lecture 14)

14:30-14:45 Stability Analysis of Geology Structures Controlled Tunnel Profiles – K. Winn (Theme Lecture 15)

14:45-15:00 Failure Law of Surrounding Rock of Rectangular Crossheading at Fully-Mechanized Caving Face in Deep Thick Coal Seams and Its Repair Support Technology – Jian-xi Ren (Theme Lecture 16)

Plenary Session 7 – Geo-Environmental Mechanics and Engineering 2 – In Celebration of the 70th Birthday of Professor Maurice B. Dusseault — **Wang Gungwu Theatre, GH**
Chairman: Shen-de Yin

15:00-15:15 Experimental Study of Glauberite Salt Rock Creep under Compression and Dissolution Coupling Effect – Wei-guo Liang (Theme Lecture 17)

15:15-15:30 Mechanism of Casing Damage and Control Method in Daqing Oil field – Jian-jun Liu (Theme Lecture 18)

15:30-15:40 Finite Element Solution of Elastoplastic Consolidation in Strain-softening Porous Media – H. Jiang (Paper 32)

15:40-15:50 Geomechanics Parameter Characterization Using Numerical Modeling and Hydraulic Fracturing Test – S. K. Zhang (Paper 33)

15:50-16:00 Deformation Response of Oil Reservoir Induced by Water Injection – Y. X. Zheng (Paper 34)

16:00-16:10 Coffee-Tea Break Foyer, Graduate House (GH)

Parallel Session 4 – Slope Stability and Landslides 3 **Seminar Room P05-01, GH**
Chairman: Sergio Lourenco

16:10-16:20 Shearing Rate Effect on Residual Strength of Slip Soils and Its Impact on the Deformation Characteristics of Landslides – L. N. Wang (Paper 35)

16:20-16:30 Completely Weathered Sandstone Slope Failure During Highway Construction and Its Remedy – Z. J. Wu (Paper 36)

16:30-16:40 Mitigation Measures after "8.8" Zhouqu Debris Flow Disaster in Sanyanyu Valley, China – M.Q. Xiong (Paper 37)

16:40-16:50 Response of Loess Landslide to Rainfall: Observation From Field Artificial Rainfall Experiment – G. Chen (Paper 38)

16:50-17:00 Integrated Physical-based Method for Analysis of Regional Heterogeneous Terrace Slope Stability – R. Q. Zeng (Paper 39)

17:00-17:10 Analysis of Potential Surfaces of Multi-stage Slope Based on Local Strength Reduction Method – Q. Deng (Paper 40)

17:10-17:20 3D Hydraulic Fracturing Stress Measurement at Qirehataer Hydropower Project – L. S. Zhou (Paper 41)

17:20-17:30 Search for Sliding Surface of Slope Based on Dynamic Strength Reduction Method – G. Q. Chen (Paper 42)

Parallel Session 5 – Mechanism of Rock and Soil Failures 3 **Wang Gungwu Theatre, GH**
Chairman: Hong Zheng

16:10-16:25 Constitutive Model of Chalk with Considering Effect of Intergranular Physicochemical Forces – Chang-fu Wei (Theme Lecture 19)

16:25-16:40 A Micro-mechanics Based Elastic-plastic Model for Saturated Porous Rocks – Jian-fu Shao (Theme Lecture 20)

16:40-16:55 Numerical Simulation of Crack Growth and Coalescence in Rock-like Materials Containing Multiple Pre-existing Flaws Using General Particle Dynamics – Xiao-ping Zhou (Theme Lecture 21)

16:55-17:10 The Diexi Paleo-Dammed Lake at Upstream of Mingjing River, Sichuan, China – Lan-sheng Wang (Theme Lecture 22)

16:10-17:20 Impact Response Characteristics of Granite with a Tunnel-like Structure – Z. Y. Tan (Paper 43)

17:20-17:30 Mechanism and Theoretical Model of Intermediate Principal Stress Effect on Rock Strength – Y. L. Zheng (Paper 44)

Closing Ceremony **Wang Gungwu Theatre, GH**
Chairman: Zhong-qi Quentin Yue

17:30-17:35 Closing Address – Xia-ting Feng

17:35-15:40 Closing Address – A. P. S. Selvadurai

17:40-17:45 Closing Address – Qihu Qian

17:45-17:50 Closing Address – Nick Barton

17:50-18:00 Summary & Thanks – Zhong-qi Quentin Yue

19:00-21:30 Dinner **Fulum Restaurant, 455-485 Queen's Road West, near HKU Main Campus MTR HKU Station Exit B2 (see map on next page)**

December 17, 2016 Saturday

Technical Site Visits in Hong Kong **Lantau Island, Hong Kong**
Leaders: Zhong-qi Quentin Yue, Chao Li and Jian Chen

9:00-12:00 Hong Kong-Zhuhai-Macao Bridge Project nearby Hong Kong International Airport and Tung Chung Town on Lantau Island

12:00-14:00 Lunch

14:00-17:00 Po Lin Monastery and Giant Buddha for Visiting Country Park in Hong Kong

Fulum Restaurant
富臨酒家
+0 Sea 海面
港島太平洋酒店
Island Pacific Hotel
万怡酒店
Marriott
華大盛品酒店
Best Western Plus Hotel Hong Kong
香港今旅酒店
Hotel Jen Hong Kong
西宝城
Westwood
MTR HKU
Station
香港大学本部校园
Main Campus of HKU
+130 m
港大研究生楼
HKU Graduate House
Robert Black
College Hotel, HKU
Symposium Banquet:
Victoria Harbour Restaurant
會議晚宴: 海港酒家
Connaught Rd W
Des Voeux Rd W
Queen's Rd W
Pok Fu Lam Rd
Bonham Rd
100 m

HONG KONG – ZHUHAI – MACAO BRIDGE (HZMB)

HONG KONG BOUNDARY CROSSING FACILITIES – RECLAMATION WORKS

CONTRACT NO. HY/2010/02

Project Background:

Client: Highways Department (HyD)
Engineer: Ove Arup & Partners Hong Kong Ltd.
Contractor: China Harbour Engineering Co. Ltd.

Reclamation works have been commissioned by the HyD of the Government of Hong Kong SAR for the construction of an artificial island in the open waters off the northeast of the Hong Kong International Airport (HKIA). The proposed HKBCF is located on the artificial island and linked by the Hong Kong Link Road (HKLR) of the HZMB, the proposed Tuen Mun- Chek Lap Kok Link (TM-CLKL) and the roads leading to HKIA

Major Items of Works:

- 6,140 m long seawall;
- Reclamation of about 150 hectares of land for development of HKBCF with proposed final formation level at +5.5mPD;
- Ground improvement works shall be carried out to control the residual settlement to less than 500mm over a design life of 50 years from handover of the site.

List of Abstracts

Keynote 1

Professor Herbert Einstein

Massachusetts Institute of Technology, USA

Keynote Title

Construction and Operation of Tunnels in the Urban Environment - A Risk Based Approach

Professor Herbert H. Einstein of Civil and Environmental Engineering at the Massachusetts Institute of Technology, received his Dipl. Ing. and Sc. D. in Civil Engineering from ETH-Zürich. His teaching and research areas are underground construction, rock mechanics and engineering geology. Professor Einstein has been involved as an advisor, consultant and researcher in issues related to underground construction, rock mechanics and rock engineering and natural hazards, notably landslides, and in waste repository problems. He has been and is member of a number of national and international technical/scientific committees and advisory boards; he is also co-editor of the journal, Rock Mechanics and Rock Engineering and member of the editorial board of Tunnelling and Underground Space Technology.

Professor Einstein is author or co-author of over 250 publications in his areas of expertise. He was the recipient of several awards such as the prestigious Müller lecture of the International Society for Rock Mechanics, the "Outstanding Contributions to Rock Mechanics" award of the American Rock Mechanics Association and the Outstanding Educator Award" of the Underground Construction Association of the SMME. He also received several teaching awards from his Department and from the School of Engineering.

Construction and Operation of Tunnels in the Urban Environment - A Risk Based Approach

H.H. Einstein[*#] and R. L. Sousa
Department of Civil Engineering, Massachusetts Institute of Technology, Cambridge, USA

*Corresponding author: einstein@mit.edu
[#] Presenter: einstein@mit.edu

Tunnels like most infrastructure projects affect and are affected by the local natural and human-made environment. A major problem is the fact that this interaction is difficult to assess and predict because of the complexity of the interaction and the inherent uncertainty of the influencing factors.

This lecture will address the problem through formal risk assessment, - analysis and – management. Specifically, the construction risks and some of the operational risks will be discussed. Construction risks are those related to cost and time, the transport of material, and deformation and failure (Figure 1). Amongst the operational risks the lecture will concentrate on those associated with climate change affecting large cities (Figure 2).

Figure 1. Porto Metro Daylight Collapse - from R.L. Sousa Ph.D. Thesis, MIT, 2010.

Figure 2. South Ferry Station after Hurricane Sandy 2012 - from Web.

Keynote 2

Professor Qihu Qian
State Key Laboratory of Explosion Shock Disaster Prevention and Mitigation, Nanjing

Keynote Title

Lessons Learned from Design of Surrounding Supports in Rock Mass with High In-situ Stresses

Professor Qihu Qian, graduated from the Harbin Military Engineering Institute and got his engineering bachelor's degree in 1960. As a postgraduate student, he graduated from Moscow Gobichev Military Engineering Academy in the former Soviet Union and got his candidate doctor's degree in 1965. He was appointed as associate professor in 1980 and professor in 1986. He has been engaged in civil engineering and rock mechanics and engineering for several decades and finished a large amount of research work. He has published over 200 papers on technical journals, including "Geotechnique" and "Canadian Geotechnical Journal". He has published several monographs, such as Impact and Explosion Effects in Rock and Soil, Study of the Development and Utilization of Underground Space in Chinese Cities, Calculation Theory for Advanced Protective Structures. He and his research group have won the Important Scientific Award at the National Science Conference and National Awards for Science and Technology Progress for their achievements in the propagation of stress wave in rock and soil, stress wave passing through fractured rock masses and interaction of stress wave with structures in rock masses.

Professor Qian won the title of the outstanding middle-young aged specialist by the State Council and the advanced scientist in China's universities in 1990. In May 1994, he was elected as a fellow of the Chinese Academy of Engineering (CAE). He was a member of the 8th, 9th and 10th national committees of the Chinese People's Consultation Conference, deputy director of the CAE Civil Engineering Division in 1994–2000, deputy director of the CAE Engineering Management Division in 2000–2004, vice-president of the International Society for Rock Mechanics in 2003–2007, Asian director of the International Associated Research Centers for the Urban Underground Space (ACUUS), honorary president of the Chinese Society for Blasting Engineering, president of the Chinese Society for Rock Mechanics and Engineering, standing director of the council of the Chinese Civil Engineering Society (CCES), chairman of the Protective Engineering Sub-society of CCES, and concurrently a professor of many universities. He is a member of the Specialists' Committee of China's South-to-North Water Diversion Project, deputy head of the experts group of China's Nuclear Wastes Deep Geological Treatment Project, editor-in-chief of Journal of Rock Mechanics and Geotechnical Engineering, and a member of the Editorial Board of Chinese Journal of Rock Mechanics and Engineering, Earthquake Engineering and Engineering Vibration and China Civil Engineering Journal.

Lessons Learned from Design of Surrounding Supports in Rock Mass with High In-situ Stresses

Q. H. Qian[*#]
State Key Laboratory of Explosion Shock Disaster Prevention and Mitigation, Nanjing, China

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Presenter: gcyqqh@163.com

This keynote lecture deals with the deformation, failure analysis and supporting design of surrounding rocks associated with cavern excavation in rock mass with high in-situ stresses. It uses the case study of the excavation and surrounding rock support design of underground cavern groups in the Jinping First Stage Hydropower Station. The excavation encountered the problems of over-large deformation of surrounding rocks and severe over loadings of supporting bolts and cables. On the basis of numerical modelling, the lecture analyses the reasons of the over-large deformation and over-loading of bolts and cables. Thus, it points out that the conventional continuum elastic-plastic mechanics can be applicable only to the plastic yield of surrounding rocks. It cannot correctly analyse the crack generation and propagation in the surrounding rock masses. In other words, it cannot correctly analyse the rheological behaviour or time-dependent deformation of surrounding rock masses. It further points out that the key feature of the rheological behaviour of surrounding rocks with high in-situ stresses is the formation of multi-zoning ruptures, i.e., the phenomenon of zonal disintegration. On the basis of theoretical analysis, it summarizes the general rules of the zonal disintegration in surrounding rock masses with high in-situ stresses and presents the suggestions for supporting of the surrounding rock masses with zonal disintegration. Finally, it uses the actual effects of supporting methods in the Jinping First Stage Hydropower Station to verify and validate these suggestions.

Keynote 3

Professor Xia-ting Feng
State Key Laboratory of Geomechanics and Geotechnical Engineering, CAS Institute of Rock and Soil Mechanics

Keynote Title

Rock mass Behaviour during Excavation of China Jinping Underground Laboratories with Overburden of 2400 m

Professor Xia-Ting Feng, BSc, PhD, obtained his BSc degree in Mining Engineering from the Northeast University of Science and Technology in Shenyang, China, in 1986 and his PhD in rock mechanics from the Northeastern University, China, in 1992. Then he has been affiliated as Lecturer, Associate Professor (from 1993-1996) and Professor (from 1996-2001) at the same university, from September 1995 to March 1996 as a Visiting Researcher and from December 1996 to November 1997 as a ITIT Special Research Officer at National Institute for Resource and Environment, Tsukuba, Japan, and from May to November 1996 as a Senior Research Officer at Department of Mining Engineering, the University of Witwatersrand, South Africa. As a Professor of Hundred Talent Program of the Chinese Academy of Sciences, he joined Institute of Rock and Soil Mechanics, the Chinese Academy of Sciences in 1998, from 2001-2003 as Vice Director in Charge and from 2003-2005 as Director of this institute, from 2001-2007 as Director of Key Laboratory of Rock and Soil Mechanics, Chinese Academy of Sciences, from 2007-present as Director of State Key Laboratory of Geomechanics and Geotechnical Engineering. He worked in Imperial College, UK, the University of Oklahoma, USA, Royal Institute of Technology, Sweden, and Lille University of Science and Technology, France as a Visiting Professor or Academic Visitor in short term. From 2011-2015 he is President of International Society for Rock Mechanics(ISRM), from 2012-present he is President of Chinese Society for Rock Mechanics and Engineering (CSRME).

Rock Mass behaviour during excavation of China Jinping underground laboratories with overburden of 2400 m

X. T. Feng[*#1] and S. J. Li[1]

[1] State Key Laboratory of Geomechanics and Geotechnical Engineering, Institute of Rock and Soil Mechanics, Chinese Academy of Sciences, Wuhan, Hubei 430071, China

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The China Jinping Underground Laboratory (CJPL) is currently the world's deepest laboratory in overburden. We focused on the second phase project of CJPL, namely CJPL-II. Rock mass behaviors and characteristics of evolution during the whole excavation process were real-timely obtained via a comprehensive monitoring approach, which included the measurement of deformation and fracturing of rock mass, elastic wave testing, distribution stress testing, micro-seismic and AE monitoring, 3D laser scanning, rock mass structure photogrammetry, rock blasting monitoring and so on. It was also achieved that the multi-scale ruptures, from micro to macro, of rock masses, as well as their deformations from excavation surface to deeper surrounding rock, were detected or monitored. This research, is greatly significant to support CJPL-II safe construction and its long-term operation and to explore the deep problems of rock mechanics and engineering science.

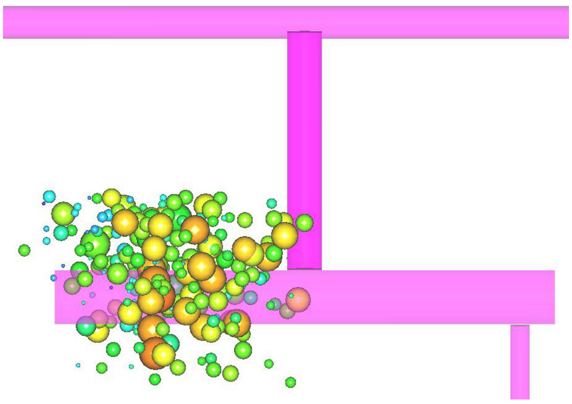

Figure 1. Distribution of seismic activities of an intensive rockburst.

Acknowledgements

State Key Research Development Program of China (Grant No.2016YFC0600702).

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Keynote 4

Professor Manchao He

CUMTB, Beijing

Keynote Title

Geo-disaster Prediction With Double-blocks Mechanics Theory Based On Newton Force Measurement

Professor Manchao He is currently an Academician in Chinese Academy of Sciences, Professor at China University of Mining and Technology, Beijing (CUMTB). He is also the Director of State Key Laboratory for Geomechanics and Deep Underground Engineering in Beijing, China. He is recognized as the leader of the Chinese Union for Mining Innovation (CUMI). And he served as the Vice President at Large of International Society for Rock Mechanics (ISRM), Chairman of ISRM Education Fund Committee, and President of ISRM Chinese National Group.

He received his Bachelor and Master Degree in engineering geology from Changchun College of Geology in 1981 and 1985 respectively, and obtained his Ph.D. in Engineering Mechanics from CUMTB in 1989. He got an Honorary Doctorate from University of Mons in Belgium in 2012. He mainly engaged in the research of Rock Mechanics and Engineering, including landslide, active fault stability analysis, monitoring and control, mining technologies, rockburst mechanism, etc. He has published 4 books and over 190 papers in technical journals and in conference proceedings. He also serves on the Editorial Board of several Journals, and received 5 National Prizes and awards in his career.

Geo-disaster Prediction with Double-blocks Mechanics Theory Based on Newton Force Measurement

Manchao He

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The earthquake and landslide are two major geological disasters causing huge casualties and economic losses each year across the world. According to the statistics, many of the landslides are caused by earthquakes, and over ninety percent of the earthquakes occurred as the results of the motion of active faults, such as the 2008 Wenchuan earthquake (M8.0) and the 2015 Nepal earthquake (M8.1). Both landslide and earthquake can be shown in a model of double-blocks separated by a sliding plane. The key point for geo-disaster prediction is the Newton force variation along the sliding plane. However, measurement of the Newton force on the sliding plane is extremely difficult. Therefore, most of the current researches on earthquake and landslide rely on monitoring the displacement between the two blocks. The relative displacement between the two blocks is considered the necessary condition but not the sufficient condition for the occurrence of the earthquake and/or landslide. This may be the reason for the general recognition of the limitation on geo-disaster prediction. The presentation will introduce a study on the theory of double-blocks mechanics including the measurement of the Newton force, which is the necessary and sufficient conditions for initiating a geological disaster due to the block motion, using the so-called constant-resistance and large-deformation cable with negative Poisson's ratio effect. Applications for geo-disaster prediction will also be described in this presentation.

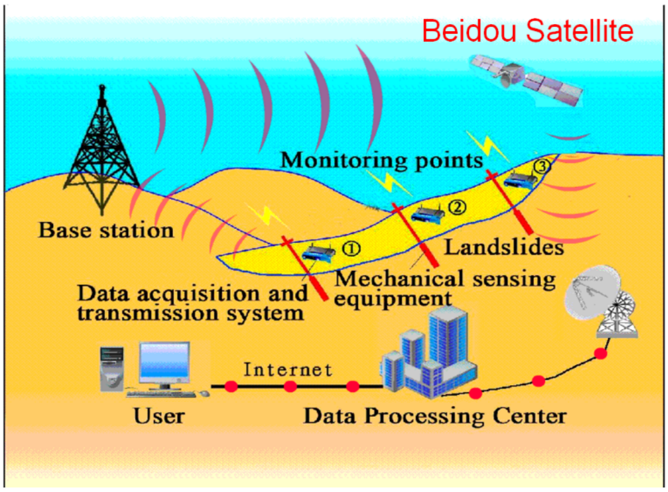

Figure 1. Remote-sensing system for motoring and forecasting the landslides.

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Keynote 5

Professor Nick Barton

NB&A, Oslo

Keynote Title

Cavern and Tunnel Failures
due to Adverse Structural Geology
and
due to Inadequate Support Designs

Nick Barton obtained a London University B.Sc. in Civil Engineering from King's College in 1966, and a Ph.D. concerning shear strength and rock slope stability from Imperial College in 1971. He worked for two long periods at NGI in Oslo, and for four years at TerraTek in Salt Lake City. Since 2000 he has had his own international rock engineering one-man consultancy, Nick Barton & Associates, based in Oslo and São Paulo.

He has consulted on several hundred rock engineering projects in a total of 38 countries during 45 years, has 260 publications as first or single author, and has written two books, one on TBM prognosis, the other linking rock quality and seismic attributes of rock masses at all scales. He is currently writing a book with Bandis: Engineering in jointed and faulted rock (expected 2017). He has ten international awards including the 6th Müller Lecture of ISRM. He developed the widely used Q-system for classifying rock masses, and for selecting rock tunnel and cavern single-shell support in 1974. He was originator of the rock joint shear strength parameters JRC and JCS and co-developer of the resulting Barton-Bandis constitutive laws for rock joint coupled M-H modelling in 1982, which was incorporated as a sub-routine in UDEC-BB in 1985. He has also developed the Q*tbm* prognosis method and Q*slope* for selecting maintenance-free rock cutting and bench-face angles. His chief areas of consulting activity have been in hydropower tunnelling and cavern construction and performance, nuclear waste disposal site characterization, metro tunnels and caverns, and site characterization at high dams. He has given more than thirty five keynote lectures in international conferences.

Cavern and Tunnel Failures due to Adverse Structural Geology and Inadequate-in-the-Circumstances Support Designs

N. Barton
NB&A, Oslo, Norway

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Some remarkable cavern and tunnel failures are described in this paper. Very regrettably, the collapses are sometimes fatal for some trusting tunnel or cavern workers. There is often an adverse design in relation to the special circumstances. Failure is most frequent during construction, with only the temporary support to resist the unexpected challenges of adverse structural geology. In fact the three most serious cases shown have lattice girders or steel arches as one of the components of the temporary support, prior to concrete lining. It is usually a surprise to read that the steel arches provide the softest of deformation resistance, because of the difficulty of making really good contact with the uneven rock. These partly free-standing girders or arches, and their footings, deform too much before fully resisting radial deformation, thereby potentially reducing the shear strength of the rock mass. Such measures (lattice girders and steel sets) should never be part of the Q-system of tunnel and cavern support. A systematically bolted, and intimately supporting alternative is needed to reduce the risk of collapse. The solution is called rib-reinforced shotcrete arches, or RRS when used in the single-shell Norwegian NMT Q-value based tunnel and cavern support schemes. The level of risk compared to using the Austrian-style double-shell NATM is thereby much reduced.

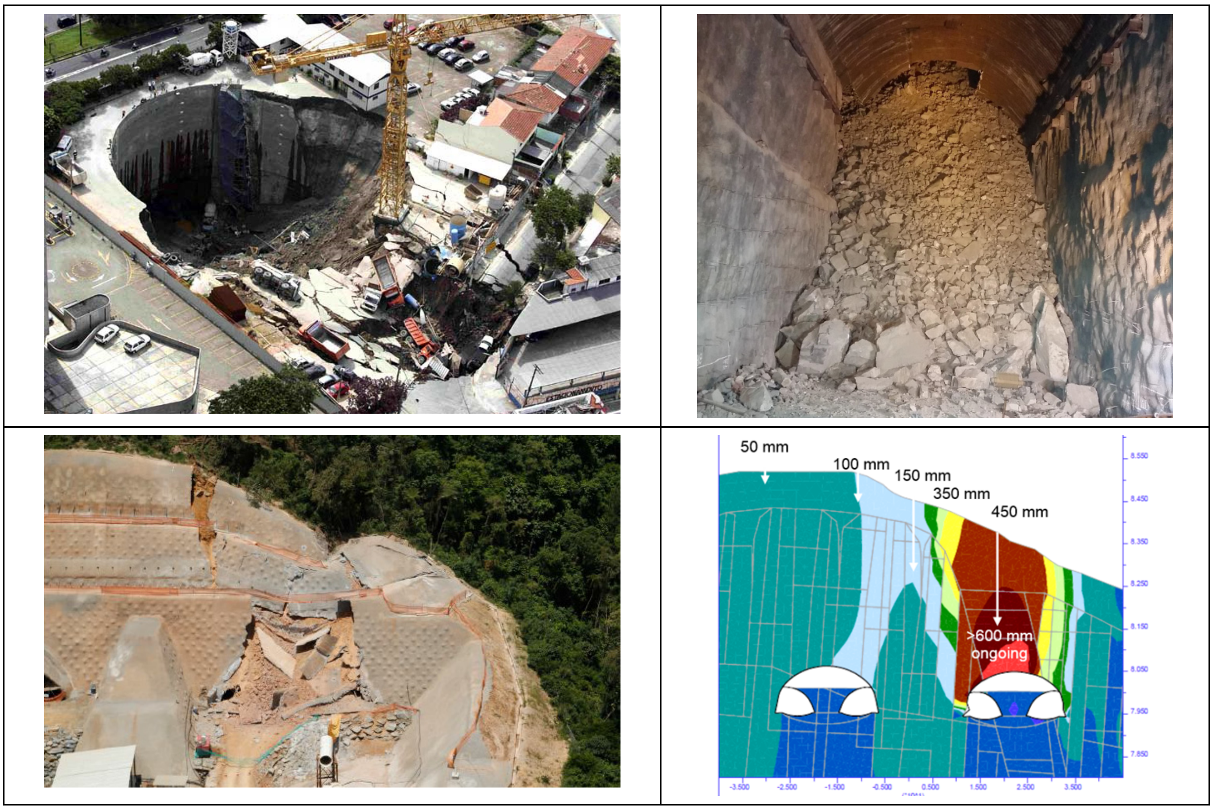

Figure 1. Examples of cavern and tunnel failures. Unexpected loadings from unexpected structural geologies, and the use of 'deformation-inviting' lattice girders or steel arches, are the combined culprits of such failures, which tend to occur in the temporary support phase of NATM projects. Bolting may or may not be absent.

Keynote 6

Professor A. Patrick S. Selvadurai

McGill University, Montréal, Canada

Keynote Title

Thermo-Poromechanics of Geologic Media

A.P.S. Selvadurai is currently *William Scott Professor* and *James McGill Professor* in the Department of Civil Engineering and Applied Mechanics, McGill University, Montréal, Canada. He obtained his PhD degree in Theoretical Mechanics from the University of Nottingham, under the tutelage of the world-renowned continuum mechanicist, the late A.J.M. Spencer FRS, and the first ever DSc in Theoretical Mechanics for research into *Mathematical Modelling of Problems in Geomechanics and Elastomechanics*.

He was Head of the Department of Civil Engineering at Carleton University from 1982 to 1991 and Chair of the Department of Civil Engineering and Applied Mechanics, at McGill till 1997. He has held visiting appointments at Universities in the UK, France, Germany, Australia, Brazil, Belgium, New Zealand, Hong Kong and Japan. In 1998, Dr. Selvadurai received the *Humboldt Senior Scientist Award* (Humboldt Foundation of Germany). In 2000, he became the first civil engineer to be awarded the *Killam Research Fellowship* (Canada Council for the Arts), in recognition his outstanding research record. In 2001 he was awarded the Inaugural *John Booker Medal* (International Association for Computer Methods and Advances in Geomechanics). In 2003 he received the prestigious *Max Planck Research Prize* in the Engineering Sciences, awarded by the Max Planck Foundation, Germany. In 2007, he received *The Killam Prize for Engineering*, awarded by the Canada Council for the Arts and the *CANCAM Gold Medal*, awarded by the Central Committee for Canadian Congresses of Applied Mechanics, for his sustained contributions to the discipline. In 2008, he received the *IACMAG Medal* for Outstanding Accomplishments in Theoretical, Computational and Experimental Geomechanics and in 2010 he received the *ALERT Medal* awarded by Alliance of Laboratories in Europe for Research and Technology. In 2012, he was awarded the degree of *Docteur Honoris Causa* by the Institut Polytechnique de Grenoble, France. In 2013, he was awarded *The Eric Reissner Medal* of the International Conference on Computational and Experimental Engineering and Sciences and *The Maurice A. Biot Medal* of the American Society of Civil Engineers Engineering Mechanics Institute.

He has published extensively in archival journals (289 Papers) computational geomechanics and experimental mechanics. He is the author or co-author of texts devoted to *Elastic Analysis of Soil-Foundation Interaction* (Elsevier, 1979), *Elasticity and Geomechanics* (with R.O. Davis) (Cambridge Univ Press, 1996), *Partial Differential Equations in Mechanics Vols. 1&2* (Springer-Verlag, 2000); *Plasticity and Geomechanics* (with R.O. Davis) (Cambridge Univ Press, 2002), *Transport in Porous Media* (with Y. Ichikawa) (Springer-Verlag, 2012) and *Thermo-Poroelasticity and Geomechanics* (with A.P. Suvorov) (Cambridge Univ Press, 2016). He serves on the Editorial Boards of nine leading International Journals devoted to *Geomechanics, Applied Mechanics, Computational Mechanics* and *Engineering Mathematics.* He is a Fellow *the Royal Society of Canada*, *The Canadian Academy of Engineering*, *The Engineering Institute of Canada*, *The American Academy of Mechanics*, *The Canadian Society for Civil Engineering* and *The Institute for Mathematics Applications and its Applications* (*UK*). He is a Chartered Engineer as well as a Chartered Mathematician.

Thermo-Poromechanics of Geologic Media

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Coupled processes involving mechanical deformations (M), fluid transport (H) and heat transfer (T) in fluid-saturated porous media have a wide range of applications to engineering and geosciences. The most developed area of application of THM modelling is in the area of deep geological disposal of heat emitting nuclear fuel waste, where fluid transport induced by heat generated by radioactive decay can influence the mechanical integrity of the rock, which can influence fluid transport in the rock mass. In recent years the scope of application of THM modelling has been extended to cover a number of other areas including thermal stimulation of energy resources bearing rocks leading to enhanced oil recovery, energy resources transportation in the form of liquefied natural gas, large-scale geothermal energy extraction by hydraulic fracturing and small-scale energy extraction using ground source heat pumps, deep geologic disposal of greenhouse gases in supercritical form, mechanics of earthquakes that can be influenced by heat generation during frictional slip, glacial loading of geologic sequestration settings, etc. Extensive references to applications involving these areas are given by Selvadurai and Suvorov (2016). In this paper, the scope of application of THM developments is restricted to the development of experimental facilities that can be used to validate THM models where the mechanical deformations of the geologic medium are modelled by Hookean behaviour, the fluid transport is modelled by appeal to Darcy's law and the heat transfer process is restricted to heat conduction governed by Fourier's law. The research involves the development of a novel experimental configuration, which consists of a saturated cylinder of the rock with an axially placed sealed, partially drilled fluid-filled cavity. The boundary heating of the cylinder results in fluid pressure generation in a fluid-filled cavity, which provides the signature for the validation of the theoretical modelling and computational simulations. The experiments are conducted on a fine to medium grained granite and an argillaceous limestone that consist of a calcite-quartzite nodular regions separated by argillaceous partings, to validate the approach.

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Keynote 7

Professor Maurice B. Dusseault

University of Waterloo
Waterloo, Ontario, Canada

Keynote Title
Deep Energy Geomechanics:
Extraction, Storage, Disposal

Maurice carries out research in coupled problems in geomechanics including thermal and non-thermal oil production, wellbore integrity, deep disposal technologies for solid and liquid wastes, hydraulic fracture mechanics, CO_2 sequestration in saline aquifers, shale gas and shale oil mechanics, and compressed air energy storage in salt caverns. He holds over 80 international patents on several different subjects and has co-authored two textbooks with John Franklin (former ISRM President, deceased 2012) as well as 525 full text conference and journal articles.

He has started five different companies over the years in various geomechanics domains. Maurice works with governments and industry as an advisor and professional instructor in petroleum geomechanics. He was a Society of Petroleum Engineers Distinguished Lecturer in 2002-2003, visiting 19 countries and 28 separate SPE sections, speaking on New Oil Production Technologies. He teaches a number of professional short courses in subjects such as production approaches, petroleum geomechanics, waste disposal, and sand control, presented in over 21 different countries in the last 15 years.

Current projects are focused in these areas: 1) Hydraulic fracturing of naturally fractured rock masses in differential stress states; 2) Work, energy and stress-strain responses of deep stressed rock masses (reservoirs, mines, geothermal reservoirs); 3) Rock-cement-casing interaction and gas seepage along oil and gas wells; 4) THM coupling in naturally fractured rock masses; 5) Monitoring deformation in rock masses using surface and subsurface methods; 6) Storage of energy from stochastic renewable sources as compressed air in dissolved salt caverns.

Deep Energy Geomechanics: Extraction, Storage, Disposal

Maurice B Dusseault[#*1]
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Energy issues are emerging as the dominant socio-economic factors in the first half of the 21st century as plans for decarbonization, increasing renewables, storing energy, and safely disposing wastes are pursued. These plans will transform the industrial and social landscapes around us, and Geomechanics issues are deeply implicated in all of these plans.

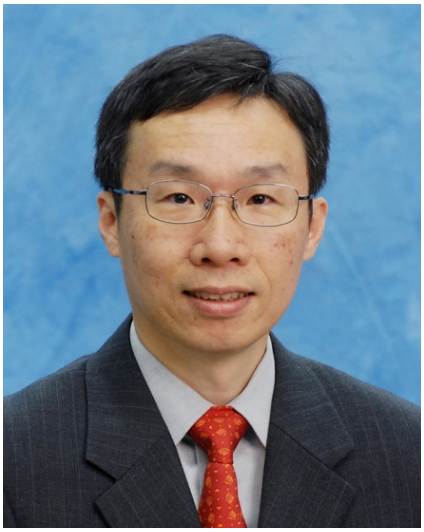
The energy extraction discussion focusses on geothermal and natural gas issues. Hydraulic fracturing of naturally fractured systems is key, and making suitable models with predictive capability for this is a challenge. Through poroelastic processes, pressure and heat changes to thermoelastic strains and massive, kilometre-scale stress changes, with profound effects in the system geomechanics. Shrinkage enhances the flow capacity in a naturally fractured system, helping explain phenomena such as the long depletion tail for shale gas reservoirs and the increases in flow capacity for geothermal projects in intermediate and long times. Increasing risk of induced seismicity is associated with km-scale stress changes, and the establishment of a strong link between rock mechanics and geophysics is seen as a key element in developing predictive capacity in models.

Energy storage geomechanics involves at least two major possibilities: compressed air, methane, or oil and other hydrocarbon storage in salt caverns or porous reservoirs; and heat storage in deep geothermal reservoirs (liquid or hot, dry rock). Salt presents unique properties in geomechanics: it is essentially impermeable, but it creeps under engineering stresses and temperatures, a major design issue. China is currently developing a Strategic Oil Reserve capability in salt, as the USA did a generation ago. Large-scale heat storage in geothermal reservoirs is a possible means of increasing the efficiency of solar power: efficiencies as high as 75% are feasible in a solar heat extraction and storage configuration. Geomechanics issues are similar to those of conventional geothermal energy, but community-scale thermal storage is unprecedented at this time, and no one really has any predictive models for jointed rock mass behaviour under thermal cycling of perhaps 100°C each year.

Deep waste disposal involves waste injection to achieve permanent, secure entomb-ment. Gaseous wastes (acid gas: CO_2 and traces of H_2S) have been injected at depth for over a generation, but this scale may be exceeded if the O&G industry adopts large-scale CO_2 sequestration. Issues such as chemicophysical reactions that dissolve minerals (carbonates) or strip the water from clays in shale cap rock are essentially geomechanics issues related to volume and permeability changes. Wellbore integrity has emerged as a critical aspect of well decommissioning in the O&G industry, and it is known to be a geomechanics issue. Large-scale produced water injection is generating earthquakes of substantial magnitude in Oklahoma and Colorado in particular, another geomechanics issue. Finally, deep disposal of particulate solid wastes (drill cuttings, tank bottoms and sludges…) arising in the O&G industry is now taking place at many sites in the world: continuous fracturing is the process.

Focusing on geomechanics and energy leads to a clear "shopping list" of modelling and measurement methods that have to be developed and implemented to provide secure energy during the transition to a decarbonized world.

Keynote 8



Ir H.N. Wong

Geotechnical Engineering Office,
Hong Kong

Keynote Title

Urban Landslide Risk Management amid the Challenge of Climate Change

Ir H.N. Wong is the Head of Geotechnical Engineering Office (GEO), Civil Engineering and Development Department of the Hong Kong SAR Government, where he oversees geo-hazard management in Hong Kong and a wide range of geotechnical services provided by the Office. He is a geotechnical engineer, and is renowned for his expertise in landslide risk management. He has also served in prominent international bodies on slope engineering, landslide researches and risk management, including the Joint Technical Committee on Landslides and Engineered Slopes, Scientific Committee of International School on Landslide Risk Assessment and Mitigation, and International Advisory Board of European Commission's Framework Programme for Research and Technological Development on Management of Landslide Risk in Europe.

The GEO was set up in 1977 by the Hong Kong Government as the central authority to exercise geotechnical control of development and manage slope safety in Hong Kong. The GEO also provides geotechnical services to the public and private sectors, including geotechnical advisory services, geological survey, ground investigation, material and compliance testing, regulation and delivery of explosives, and geotechnical information services. The GEO has also been undertaking strategic studies on cavern and underground space development in Hong Kong.

Urban Landslide Risk Management amid the Challenge of Climate Change

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The Slope Safety System that has been developed and implemented in Hong Kong is a holistic example of landslide risk management in an urbanised setting. The System comprises three strategic components for dealing with landslide risk: (i) checking of new works to contain risk increase, (ii) improvement of existing slopes to mitigate risk, and (iii) supplementary risk management measures, e.g. public education, landslide warning and emergency management, to further control risk.

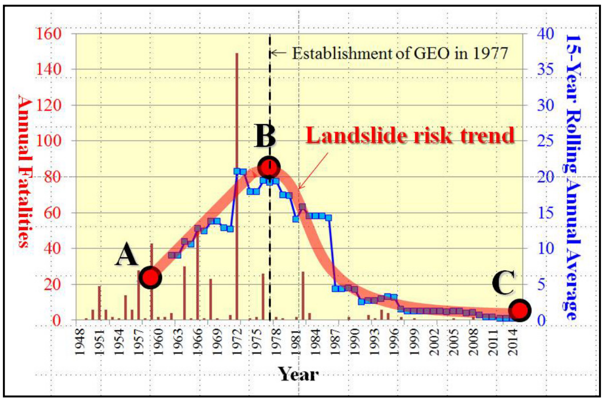

Figure 1. Landslide risk trend

While slope safety has been significantly improved as reflected in the substantial reduction in landslide fatalities (Figure 1), new challenges arising from the more frequent and severe occurrences of extreme rainfall due to climate change are anticipated. A suite of 'adaptation' and 'resilience' initiatives to strengthen urban landslide risk management amid the challenge of climate change are being pursued. These serve to anticipate adverse effects of extreme rainfall scenarios (Figure 2), enhance slope engineering practice to improve robustness and minimise damage, and strengthen the capability of the community to cope with landslide emergency.

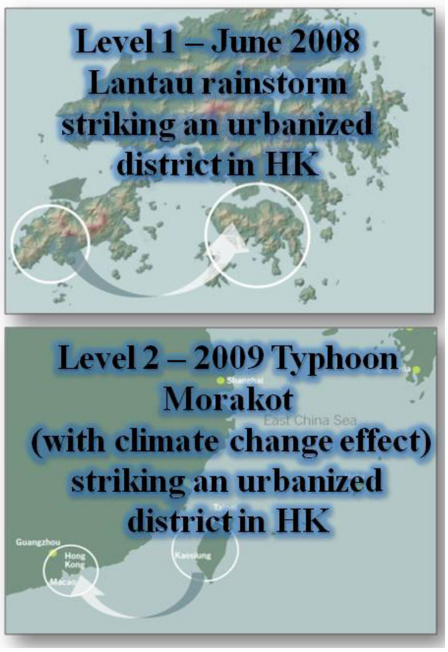

Figure 2. Vulnerability assessment of extreme rainfall scenarios

Acknowledgements

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Keynote 9

Professor Jianlin Li
China Three Gorges University,
Yichang, China

Keynote Title

Unloading Rock Mass Mechanics

Professor Li obtained a Master Degree of engineering in hydraulic structure from China Institute of Water Resources and Hydropower Research in 1985, and a Ph.D. concerning geotechnical engineering from Chongqing Construction University in 1996.He worked for 31 years at China Three Gorges University (CTGU). Professor Li is currently visiting professor in Wuhan University as well as Hohai University, meanwhile he acted as doctoral supervisor in CTGU and the chairman at key laboratory of the Three Gorges Reservoir Geological Disasters. And he was awarded "National Excellent Scientist" for his research findings. At the same time, he worked as committee member of ISRM and managing director of Chinese Society for Rock Mechanics & Engineering as well as the Chinese society of hydroelectric engineering. Professor Li also hold the post of editorial board member for periodicals like Chinese Journal of Rock Mechanics and Engineering, Rock and Soil Mechanics, Chinese Journal of Geotechnical Engineering, and others.

He has consulted on more than 60 domestic rock engineering projects during 30 years, concerning some key hydraulic and hydroelectric engineering such as Three Gorges Project, Xiaowan and Baihetan hydropower station project, etc. He has 200 publications at first or single author, and has written 9 books, basically on rock slope engineering and unloading rock mass mechanics. He has 13 national or provincial awards including the National scientific and technological progress second prize.

Based on the previous relevant theory, he and his team devoted to develop new concepts and system for unloading rock mass mechanics from 1990 to 1996.Combined with lavish experience in hydraulic and hydroelectric engineering projects, the unloading rock mass mechanics theory has been consummated in several parts including anisotropy, granite rheological, the size effect and has applied to rock engineering since 1997.From 2007, professor Li bent himself to disaster mechanism and stability evaluation as well as engineering protection of the slope in large-scale hydroelectric project.

Unloading Rock Mass Mechanics

Jianlin Li[*#]

Key Laboratory of Geological Hazards for Three Gorges Reservoir Area of Ministry of Education, China Three Gorges University, Yichang, Hubei 443002, China

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Geological environment of rock mass projects is always very complicated, and the same as its mechanical condition. There are essential distinctions between the mechanical characteristics of rock mass under unloading condition and loading condition. In this presentation, the first part is a brief introduction to the background and development of unloading rock mass mechanics, and then the research methods and content of unloading rock mass are also mentioned. Even more notably, the division of unloading zones is discussed, and a series of tests are conducted, including model test of the permanent Ship Lock of Three Gorges Project, the triaxial loading and unloading tests of sandstone samples, the rheological property of unloading rock mass, the anisotropy of unloading rock mass (relationship between stress and strain, tensile strength, deformation modulus), and the size effect of unloading rock mass (tensile strength, compressive strength, Poisson's ratio, deformation modulus). After then, the determination method of mechanics parameters and the yield criterion of unloading rock mass are presented briefly. As the three kinds of typical engineering examples, slope engineering, dam shoulder and underground engineering are used to introduce the engineering application of unloading rock mass mechanics.

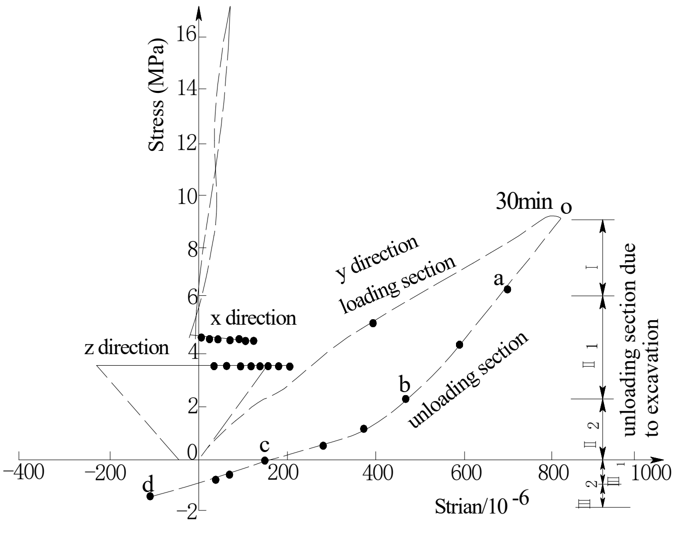

Figure 1. Rock mass unloading stress-strain relationship

Acknowledgements

Many thanks to the efforts of the organizing committee, thank you for listening.

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Keynote 10
Univ. Prof. Dr.-Ing. habil. Theodoros Triantafyllidis

Karlsruhe Institute of Technology, Germany

Keynote Title

Stability Analysis on Natural or Artificial Slopes Under Earthquake Loading Based On Non-Linear Material Models

Professor Theodoros Triantafyllidis has studied Civil Engineering at the University of Karlsruhe, where he obtained his PhD degree in 1984 concerning the dynamic subsoil coupling between adjacent foundations. In 1989 he obtained his habilitation degree at the Faculty of Civil and Survey Engineering of the University of Karlsruhe on the BEM dynamic formulation with half-space Green's functions. He worked for several years as Group Leader, Technical Manager and Head of Central Technical Division at well-known international foundation construction companies. In 1998 he became Professor and Director at the Institute for Foundation Engineering and Soil Mechanics at the Ruhr-University of Bochum where he worked until 2007. Since 2007 he is Professor and Director of the Institute for Soil Mechanics and Rock Mechanics at the University (TH) Karlsruhe now KIT Karlsruhe Institute of Technology, where he initiated several scientific fundamental and applied projects and research groups.

He is author and editor of 5 books and has contributed as author and co-author to further 8 books. He has more than 200 publications in peer-reviewed international journals and he is reviewer for more than 12 scientific international journals. He is Member of the Editorial Board in international journals as "Soil Dynamics and Earthquake Engineering" and "Acta Geotechnica". He has also obtained 5 patents in Foundation Engineering. He is appointed as Inspector for EBA (Federal German Railway Authority) for railway construction activities including foundation engineering, tunnelling, soil dynamics, geosynthetics and micro tunnelling since 2002.

He is member of several international societies as the German Society for geotechnical Engineering (DGGT), the Society of Soil Mechanics and Foundation Engineering (ISSMFE), the Technical Chamber of Greece, the International Association for Advanced Boundary Element Methods (IAABEM) and of the Hong Kong Institution of Engineers (HHKIE). He has obtained several awards and prizes. He has been session chairman of more than 15 international conferences and has given more than 25 keynote lectures in international conferences. His main areas of consulting activities are in the fields of foundations of structures on soft ground, stability of slopes, determination of soil parameters in the case of earthquake for the foundation of a nuclear power plant as well as estimation of surface waves caused by travelling trains in the close proximity due higher train velocities. He was acting as consultant in excavations in urban environments under difficult ground conditions. He has long-term academic experience in teaching soil mechanics and rock mechanics and he is supervisor of more than 30 dissertations and 4 habilitations.

Stability Analysis on Natural or Artificial Slopes under Earthquake Loading Based on Non-Linear Material Models

Theodoros Triantafyllidis

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The dynamic analysis of natural or manmade slopes as part of the renaturation of old lignite borrow areas in the form of residual lakes is an ongoing subject of fundamental and applied research. Under seismic loading and nearly saturated conditions effects of liquefaction, phase separation between the soil constituents or large deformations due to cyclic mobility may affect the stability of the slope itself and the nearby structures. In order to study these effects, non-linear material constitutive models have to be employed in order to predict the pore water pressure generation or accumulation and the reduction of the effective stress, which may trigger liquefaction. Simple examples in 1-D simulations demonstrate how the site response can change due to the pore pressure generation. In a 2-D model is shown that such non-linear wave propagation can be applied in a slope analysis and predict using FE-Methods the resulting deformation till the formation of slip surfaces. Based on these analyses a simplified engineering model can be deducted for so called "pseudo static" methods for the assessment of the overall slope stability. Furthermore, it is shown similar to Newmark's block sliding method that on overall slope stability is possible below the global safety factor of one if permanent deformations of certain magnitude are allowed without triggering further vulnerability issues. Finally, some effects of wave diffraction are based on the structure of artificial slopes up to 400 m height in lignite borrow areas in the course of renaturation process via residual lakes. Those artificial lakes of very large extent will be located in the lower Rhine river region in Germany and will be designed for a seismic loading corresponding to 2500 years return period. The non-linear analysis is capable to predict the permanent deformations of the residual lake slopes after the seismic event. The model's predictions will be verified on site with an in situ dynamic test in a part of the artificial slope.

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Keynote 11

Professor Gen-hua Shi

DDA, California

Keynote Title

Contact Theory – The Foundation of Discontinuous Computations

Professor Genhua Shi currently is a Professor at the College of Engineering & Information Technology, University of Chinese Academy of Sciences. He serves as a Senior Consultant to the China Renewable Energy Engineering Institute and the Technical Director of the DDA Centre of Yangtze River Scientific Research Institute. He is the chairman of the DDA Company in California, USA.

He obtained his BSc and MEng from Peking University, China respectively in 1963 and 1968, and his PhD from University of California at Berkeley, USA in 1988. He established the Key Block theory and Discontinuous Deformation Analysis method. They are now widely studied and applied in rock mechanics and rock engineering fields. He is the inventor of the Numerical Manifold Method, a novel method for the analysis of both continuous and discontinuous material behaviour.

He has been actively involved in many worldly famous projects related to rock mechanics in-situ test, nuclear waste storage, blasting design of rock engineering, stability analysis of rock slopes and rock foundations, underground excavation support design and construction, and dam design and dam foundation analysis. His papers have appeared in profound journals, and in significant conferences such as the series of North American Rock Mechanics Symposiums, the series of Conferences on Analysis of Discontinuous Deformation. He also received the China Natural Science Award and some other international awards.

Contact Theory – The Foundation of Discontinuous Computations

G. H. Shi
Professor, College of Engineering & Information Technology, University of Chinese Academy of Sciences
Senior Consultant, China Renewable Energy Engineering Institute
Technical Director, DDA Center, Yangtze River Scientific Research Institute

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Contacts between two general blocks A and B are the basic phenomenon of block system movements. There are three basic relations between blocks A and B:

1. Separation,

$$A \cap B = \emptyset.$$

2. Contact, all common points $A \cap B$ of block A and block B are in boundaries ∂A and ∂B of block A and block B respectively,

$$(A \cap B) \subset (\partial A \cap \partial B) \neq \emptyset.$$

3. Penetration,

$$int(A) \cap int(B) \neq \emptyset$$

Case 2 and 3 together is entrance $A \cap B \neq \emptyset$.

A new concept of an entrance block $E(A,B)$ for computing the contacts between two general A and B is introduced. Choosing a reference point $\boldsymbol{a}_0$ in block A, the entrance block $E(A,B)$ is defined as:

$$E(A,B) = B - A + \boldsymbol{a}_0 = \bigcup_{\boldsymbol{a}\in A, \boldsymbol{b}\in B} (\boldsymbol{b} - \boldsymbol{a} + \boldsymbol{a}_0) = \bigcup_{(A+\boldsymbol{x})\cap B \neq \emptyset} (\boldsymbol{x} + \boldsymbol{a}_0).$$

Entrance block $E(A,B)$ transferred the relation between blocks A and B to the relations between a point $\boldsymbol{a}_0$ and $E(A,B)$ in the following way:

(1) The distance between A and B is the distance between $\boldsymbol{a}_0$ and $E(A,B)$, $|A,B| = |\boldsymbol{a}_0, E(A,B)|$.

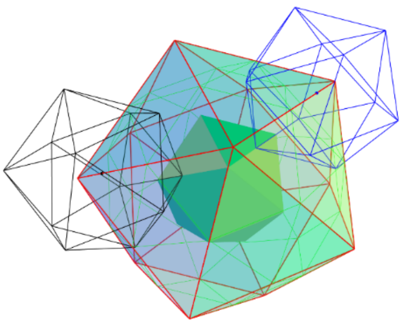
(2) $E(A,B)$ indicate the separation, contact and penetration between blocks A and B: $\boldsymbol{a}_0 \notin E(A,B) \Leftrightarrow A \cap B = \emptyset$,

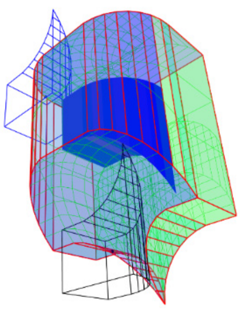
$$\boldsymbol{a}_0 \in \partial E(A,B) \Rightarrow (A \cap B) \subset (\partial A \cap \partial B) \neq \emptyset, \qquad \boldsymbol{a}_0 \in int(E(A,B)) \Leftrightarrow int(A) \cap int(B) \neq \emptyset.$$

(3) $\partial E(A,B)$ is a cover system consisting of contact polygons (for 3d) or edges (for 2d). Contact polygons are

$$E\left(A_i(2), B_j(0)\right), E\left(A_i(1), B_j(1)\right), E\left(A_i(0), B_j(2)\right)$$

which satisfying contact condition. Each contact cover defines a contact point and all closed-contact points define the movements, rotations and deformations of all blocks as in real cases. Those contact points are all the needs for the discontinuous part of computations. Following are examples of convex and complex entrance blocks $E(A,B)$, where B is the solid block, A is the frame block, $E(A,B)$ is the transparent block and $\boldsymbol{a}_0$ is the black dot.





Theme Lecture 1

Dr. Jun Yang
Department of Civil Engineering, The University of Hong Kong, China

Theme Lecture Title

Static Liquefaction and Flow Failure of Sand: Several New Findings

Dr. Jun Yang earned a bachelor's degree in civil engineering with highest honours from Zhejiang University in China and a doctorate in earthquake geotechnical engineering from Kyoto University in Japan. A member of the faculty at the University of Hong Kong since 2003, Yang has more than 170 peer-reviewed papers in journals and conference proceedings to his credit. His work on earthquake ground response, soil liquefaction, dynamic soil properties, pile foundations, and advanced testing and modeling is widely recognized by academics and practitioners. Yang sits on three technical committees of the International Society for Soil Mechanics and Geotechnical Engineering and has served on committees for a number of international conferences. His many accolades include an Outstanding Overseas Young Investigator Award in 2014 from the National Natural Science Foundation of China, a JSPS Invitation Fellowship in 2013 from Japan Society for the Promotion of Science, a Distinguished Visiting Professorship in 2013 from Shanghai Jiao Tong University, an Elected Fellow of the American Society of Civil Engineers in 2012, and an Outstanding Young Researcher Award in 2007 and a Research Output Prize in 2010, both from the University of Hong Kong.

Static Liquefaction and Flow Failure of Sand: Several New Findings

J. Yang[*1]

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Flow liquefaction of a sand mass is characterised by a sudden loss of strength and a rapid development of deformation. It can be triggered by either monotonic or cyclic loading and can produce the most catastrophic effects of all liquefaction-related phenomena. Susceptibility to flow liquefaction is a big concern in many major geotechnical applications involving, for example, hydraulically placed fills for artificial islands or tailings dams. Over the past decades, a fundamental understanding of flow liquefaction behavior has been established through well-controlled laboratory experiments on clean sand specimens. However, natural sand deposits or sand fills often are not clean, but contain a certain amount of fines (referred to as silty sand in practice). This presentation will report on some interesting findings from ongoing work, focusing on the role of non-plastic fines in altering the liquefaction potential of clean sand. Interpretation and analysis will also be given in a sound theoretical context.

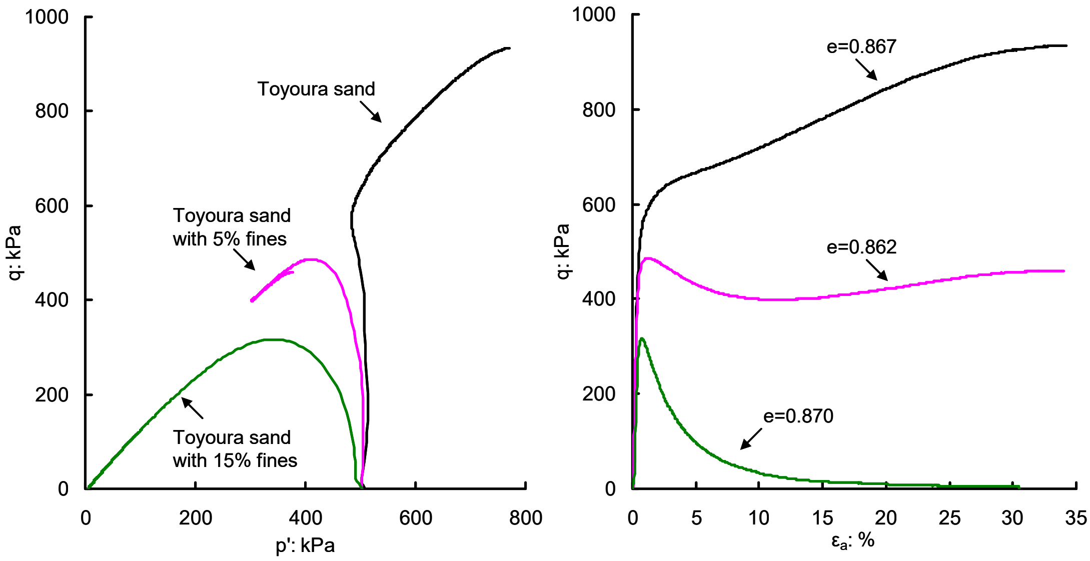

Figure 1. Observed changes in liquefaction potential of sand caused by the addition of fines

Acknowledgements

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Theme Lecture 2

Professor Qin-yong Ma
School of Civil Engineering and Architecture,
Anhui University of Science and Technology,
Huainan, China

Theme Lecture Title

Blasting Vibration Analyses of Millisecond Blasting Model Experiment with Multicircle Vertical Blastholes

Professor Qin-yong Ma is a professor of Anhui University of Science and Technology (AUST) since 1999. He got Ph.D. degree from University of Science and Technology Beijing in 2005. He served as the dean of School of Civil Engineering and Architecture of AUST from 2014 to now. His main research interests are in blasting technology and blasting vibration control, rapid excavation technology in mine and frozen soil mechanics and engineering. He is recipient of the awards including the Outstanding Teacher in Anhui Province (2011) and the Model Teacher in Anhui Province (2014).

Education:

September 1982 to July 1986, Bachelor of Engineering, Geotechnical Engineering, Anhui University of Science and Technology, Huainan, China

September 1990 to March 1992, Master of Engineering, Geotechnical Engineering, Anhui University of Science and Technology, Huainan, China

September 2001 to March 2005, Ph.D., Geotechnical Engineering, University of Science and Technology Beijing, Beijing, China

Professional Experience:

From July 1986 to October 1996, Teaching Assistant of Anhui University of Science and Technology, China

From November 1996 to November 1999, Associate Professor of Anhui University of Science and Technology, China

From December 1999, Professor of Anhui University of Science and Technology, China

From November 2014, Dean of School of Civil Engineering and Architecture, Anhui University of Science and Technology, China

Research field:

1. Blasting technology and blasting vibration control
2. Frozen soil mechanics and engineering
3. Rapid excavation technology in mine

Blasting Vibration Analyses of Millisecond Blasting Model Experiment with Multicircle Vertical Blastholes

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In order to investigate the methods to alleviate blasting vibration effect during vertical shaft excavation, millisecond blasting models with two-circle or three-circle vertical blastholes are carried out based on similarity theory. Two-circle model contains ten blastholes with four blastholes in the first circle and six blastholes in the second circle, while three-circle model has ten more blastholes in the third circle. Each circle blastholes detonate in designed delay time, and blastholes in same circle detonate simultaneously. Only one millisecond delay electric detonator is charged in one blasthole. During blasting model experiment, four blasting vibration monitor UBOX-5016 are employed, seen in figure 1. The results show that simultaneous blasting generates more blasting energy which is good for shaft excavation, but it also leads to large blasting vibration and causes overbreak. While millisecond blasting causes small blasting vibration and is conductive to controlling its shape. Spectral analyses indicate that the amplitude of millisecond blasting is much lower than that of simultaneous blasting, and millisecond blasting has a wider frequency band and main vibration frequency. With delay time increasing, waveforms of blasting vibration are independent to each other, and peak particle vibration velocity mainly depends on the maximum charge. When total charge is certain, the effective method to alleviate blasting vibration effect is increasing the delay time and limiting the maximum charge in simultaneous detonation.

Figure 1. Actual layout of blasting vibration sensors in millisecond blasting model experiment.

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Theme Lecture 3

Professor Chunan TANG
CRISR, Dalian University of Technology, Dalian, China

Theme Lecture Title

Conceptual Model of Enhanced Geothermal System based on Excavation Technology (EGS-E)

Dr. Tang, as a chair Professor (funded by Cheung Kong Scholar Programme from State Education Ministry), is the Director of the Center for Rock Instability and Seismisity Research (CRISR) of Dalian University of Technology. He was also the Vice President of the Chinese Society of Rock Mechanics CSRM, and the China National Group Chairman of International Society of Rock Mechanics. In 1984, he started his Ph.D research, in Northeastern University, Shenyang, P.R.China, and got his Ph.D in 1988. In 1991, he continued his post-doctoral work in Imperial College, London, UK (worked with Prof. J.A.Hudson). Then, as an academic visitor, he had lots of experience working in Canada, Sweden, Singapore, Switzerland and Hong Kong. He leads several major research projects in rock mechanics, especially on rock failure process analysis and monitoring in civil engineering. He is now appointed as a chief scientist for national 973 program for fundamental researcher (2014-2018). His work is funded by the “Trans-Century Training Programme Foundation for Outstanding Young Scholars in China” from the State Education Ministry and by the "Special Natural Science Foundation for Outstanding Young Scholars in China" from National Nature Science Foundation. So far, he has published about 200 technical papers on rock failure mechanisms and civil engineering, and is the author of six books of rock mechanics and the principle author of “Rock Failure Mechanisms” published by CRC Press, Taylor & Francis Group

Conceptual Model of Enhanced Geothermal System Based on Excavation Technology (EGS-E)

C.A. Tang[1*#], J. Zhao[2] and S.J.Wang[3]

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Hydrothermal resources at relatively shallow depth used today for geothermal power production are just pinpoints on a map of global scale. For the unavoidable worldwide energy shortage in the near future, it became clear that both alternative sources of energy and economies in the usage of energy are necessary, particularly on the part of the industrialized countries who were consumers of a significant proportion of the world's energy resources.

By far the biggest resource of geothermal energy is the crystalline basement in regions with normal to slightly above normal temperature gradients. The basic concept of EGS (Enhanced-Geothermal-Systems)-technology thus consists of creating or enhancing large fracture surfaces in the crystalline basement in order to hydraulically connect two or several boreholes. However, although the crystalline basement is not completely impermeable due to the presence of open fissures, fractures, or faults, its overall permeability is generally far too low to achieve and maintain production flow rates sufficient for geothermal power production. Since the first attempt to access this resource in the early 1970'th, more than a dozen research and industrial projects have been performed since than in various countries. However, the technology for the source to be accessed by artificially created flow paths and heat exchange surfaces is still not mature and the thermal power achieved so far does not meet economical standards

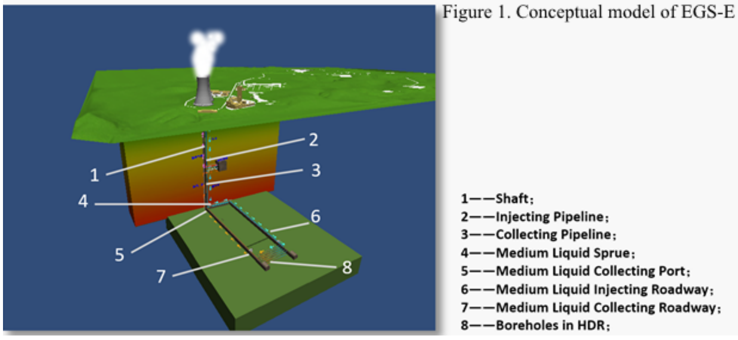

Figure 1. Conceptual model of EGS-E

EGS technology started from the idea to help fulfil future energy needs as the availability of cheap fossil and other known fuels slowly reduces. The EGS concept itself is very simple but the development of the associated technology has taken significantly longer than anticipated. Anyone with experience of natural materials such as rocks knows that there are always imponderables that have not been really understood and indeed cannot at present be dealt with in a fully satisfactory manner. Here we propose a new concept model of EGS based on excavation technology (Figure 1). In terminology, we use EGS-E for excavation technology based EGS and EGS-D for the drilling technology based EGS.

Comparing with the EGS-D, the EGS-E has the following advantages:

- The excavation technology makes a more convenient condition for construction project;
- The excavation technology makes a more substantial mass of hot rock be easily accessible at a reasonable depth;
- More fluid flow paths and heat exchangers or much bigger permeable zone can be easily created with excavation technology, particularly in the deep rock mass;
- A lower flow resistance, enabling high fluid throughputs to carry the required larger amounts of thermal energy to the surface or even underground power-conversion system;
- A sufficiently large heat exchange surface between rock and circulating fluid to enable transfer of lager amounts of thermal energy.

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Theme Lecture 4

Professor Er-nian Pan
Department of Civil Engineering,
University of Akron, OH, USA

Theme Lecture Title

An Overview of Pavement Forward and Inverse Analyses

Professor Ernian Pan obtained his BS and MS degrees from Lanzhou University and Beijing University, respectively, and his PhD from University of Colorado at Boulder. He joined the University of Akron in 2002 and was promoted to professor in 2008, with a primary appointment in the Department of Civil Engineering and a joint appointment in the Department of Applied Math. His teaching and research are in continuum/computational methods/mechanics with applications to modern engineering and Earth science problems including pavement/earth deformation due to surface and internal loadings, mechanical and electronic properties of nanoscale quantum heterostructures, and mangetoelectric effect in multiferroics composites. He has published over 300 peer-reviewed journal articles, designed a couple of software products including ***MultiSmart3D***, and co-authored a book titled *Static Green's Functions in Anisotropic Media* by Cambridge University Press. He was elected to Fellow of ASME for his contributions in Green’s functions and boundary integral equation method and to Fellow of ASCE for his contributions in modelling of layered systems.

An Overview of Pavement Forward and Inverse Analyses

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[2]School of Water Conservancy and Environment, Zhengzhou University, Zhengzhou, China

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Forward and inverse analyses of pavement are critical in pavement design, evaluation, and rehabilitation. They have been the important research and design topics in pavement engineering in the last 30 years. In this review, the forward analysis of pavement response with different models and/or methods is discussed, including some of the analytical solutions associated with the transfer matrix method, the precise integral method, etc. The inverse analysis (back calculation) of pavement layer moduli is also presented with an emphasis on the back calculation reliability for semi-rigid base pavement. The recent programs (MultSmart3D and BackSmart3D) developed by the authors are briefly introduced with some of the unique features.

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Theme Lecture 5

Professor Lin-bing Wang
Department of Civil and Environmental Engineering, Virginia Tech, VA, USA

Theme Lecture Title

Material Design: Perspectives and Status for MGI

Dr. Linbing Wang is a professor in civil engineering materials and pavement, and Director of the Center for Smart and Green Civil Systems, at Virginia Tech. He is the founding chair of the Mechanics of Pavement Committee, and the Vice Chair of the Nanomechanics and Micromechanics committee of the Engineering Mechanics Institute (EMI) of ASCE. Dr. Wang has led more than 50 research projects funded by NSF, DoD, DoA, NCHRP, FHWA, DoTs, MOST and CNSF. Specific focus of his research includes material genome, multiscale characterization, modeling and simulation; smart and sustainable technologies; energy harvesting; civil infrastructure health monitoring; innovative infrastructure assessment and performance predictions; high performance and multifunctional materials; pavement testing and mechanistic pavement design; infrastructure preservation and management; and application of remote sensing and imaging techniques.

Material Design: Perspectives and Status for MGI

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Stone-based materials including cement concrete, asphalt concrete and human augmented soils have been widely used in the construction of civil infrastructures. The mix design methods of these materials are traditionally and currently mainly empirical. The seminar will present a perspective and review of the current status of using integrated computational, experimental and database methods, or the material-genome approach for designing new and improved stone-based materials. Specific developments including the digital specimen and test method, the digital mix design method using both Discrete Element Method (DEM), Finite Element Method (FEM), and X-ray Computed Tomography will be presented will various examples. More advanced methods using multiscale modeling and characterization, which extend to quantum mechanics, molecular dynamics, and general particle mechanics will be also discussed. Based on the review of the current developments, a perspective for implementing the genome approach will be outlined.

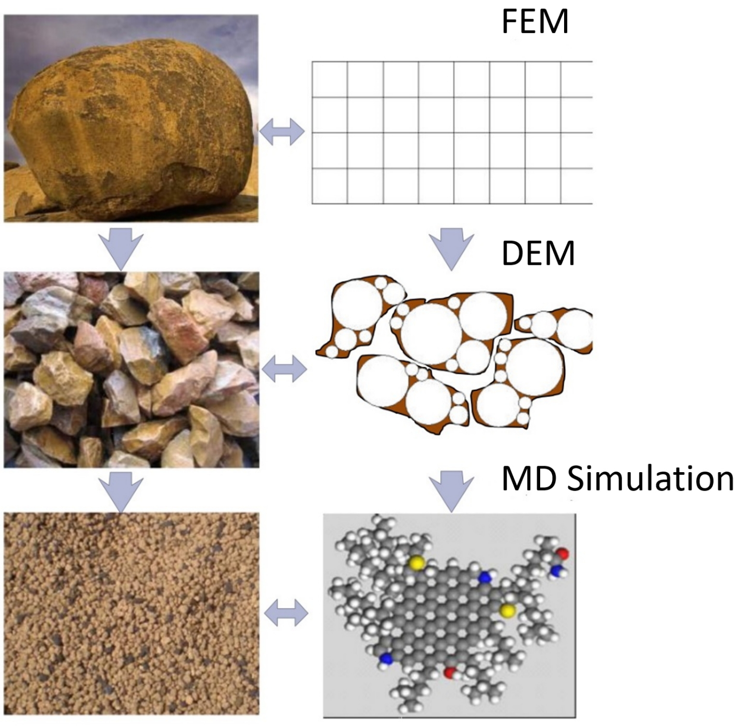

Figure 1. Integrated multi-scale approach on stone-based civil infrastructure material genome

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Theme Lecture 6

Professor Feng Zhang
Department of Civil Engineering,
Nagoya Institute of Technology,
Nagoya, Japan

Theme Lecture Title

Explanation of Thermo-Hydraulic-Mechanical Behavior of Geomaterials in So-Called Isothermal Heating Test

Dr. Feng Zhang is a professor of Nagoya Institute of Technology (NIT, National University Association of Japan) since 2005. He got Ph.D. degree from Kyoto University in 1995. He served as the head of Civil Engineering Department of NIT during 2006 to 2008 and the director of Advanced Disaster Prevention Engineering Center of NIT during 2011 to 2014. His main research interests are in constitutive modelling in soil mechanics & rock mechanics, numerical analyses in geotechnical engineering and seismic evaluation of earth structures. He is recipient of the awards including the Best Paper Medal of Soils & Foundations (2002, 2011) and the Best Paper Medal of Japan Society of Civil Engineers (2007).

Education:
March 1978 to February 1982, Bachelor of Science, Mathematics & Mechanics, Nanjing University of Science & Technology, Nanjing, China
September 1984 to February 1987, Master of Science, Mechanics, Tongji University, Shanghai, China
March 1995, Ph.D., Civil Engineering, Kyoto University, Japan

Professional Experience:
From February 1982 to August 1984, Research Associate of Suzhou University, China
From April 1995 to March 1998, Chief engineer of Chou Fukken Consultants Co. Ltd, Japan
From April 1998 to March 1999, Research Associate of Nagoya Institute of Technology, Japan
From April 1999 to March 2005, Associate Professor of Gifu University, Japan
From April 2005, Professor of Nagoya Institute of Technology, Japan
2011-2014, Director of Advanced Disaster Prevention Engineering Center, Nagoya Institute of Technology, Japan

Research field:
1. Soil mechanics & rock mechanics
2. Constitutive modelling of geomaterials
3. Numerical analyses in geotechnical engineering
4. Seismic evaluation of earth structures

Explanation of Thermo-Hydraulic-Mechanical Behavior of Geomaterials in So-Called Isothermal Heating Test

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In this paper, a thermodynamic behavior of soil observed in well-known heating tests was simulated with THM coupling finite element analysis as boundary value problem (BVP). The main purpose of the paper is to identify if it is necessary to model a phenomenon called as 'the volumetric contraction of soft clay due to heating' by introducing some extra parameters in a thermo-elastoplastic model based on which THM analyses are conducted. In the heating tests such as the works by Cekerevac and Laloui (2004), a very interesting phenomenon was found by all these researchers that, the heat-induced volumetric strain is dependent on OCR of the soil samples. That is, the specimen will change from contraction to expansion as OCR increases. In fields, similar behavior is also commonly observed that any surface ground, mainly composed of soft clay, will always settle when it is heated. The results obtained from the laboratory tests and field observation give a strong impression to researchers and engineers that some special treatments in modeling this behavior should be done. In this paper, however, we try to answer the question that, in the heating test, is the contractive behavior of soft clay when heated under constant isotropic stress condition an elementary behavior? If not, how to model contractive behavior of soil in the heating test with a rational constitutive model?

As a matter of fact, a simple thermo-elasto- viscoplastic model for soft sedimentary rock under ordinary p-q stress space has been proposed by Zhang & Zhang (2009). The model can not only describe properly the thermodynamic behavior, but also overconsolidated and time-dependent behavior of soft sedimentary rocks. And it is proved that the proposed model satisfies the 1st and 2nd thermodynamics theorems in the framework of non-equilibrium thermodynamics. In proposing the model, the geomaterial, no matter what kind of state may be, that is, normally or over consolidated, is always regarded to be expensive when its temperature increases at elementary level. Based on the model, a THM coupling analysis (Xiong et al., 2014) is conducted to prove that the heating tests is not an elementary test but a boundary value problem (BVP), and the fact that any material, including the soft clay, will exhibit expansion whenever it is heated at elementary level. It is not necessary to add any extra material parameter to model the so called 'the volumetric contraction of soft clay due to heating'. The authors hope that the results shown in this paper may give useful hint for the researchers who are interesting at modeling the thermodynamic behavior of soils.

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Theme Lecture 7

Professor Zhong-qi Quentin Yue
Department of Civil Engineering, The University of Hong Kong, Hong Kong, China

Theme Lecture Title

Cause and Mechanism of Fatal Zhenxiong Landslide of January 11, 2013

Professor Yue obtained his BSc and MSc degrees' education in earthquake and geology at Peking University in Beijing from 1979 to 1986. He obtained his Ph.D. degree's education in geotechnical engineering at Carleton University in Ottawa from 1988 to 1992. He joined HKU in 1999. Prior to joining HKU, he had a total of ten years professional working experience in Hong Kong, Ottawa and Beijing. He chartered as an engineer in Ontario in 1995 and in Hong Kong in 1998, and has been a registered professional engineer (geotechnical) in Hong Kong since 1999.

His research interests include ground investigation, soil and rock mechanics, tunnel and cavern, engineering geology, geohazards, oil/gas fields, and the earth system. He has made more than 400 publications including 2 USA/China patents. He has given more than 480 invited lectures/seminars at conferences and institutions worldwide. He is an active council/committee member of Chinese Society for Rock Mechanics and Engineering, Chinese Institution of Soil Mechanics and Geotechnical Engineering, Engineering Geology Commission and Geohazards Research Division of China Geology Society. He serves the editorial boards of many journals including Chinese Journal of Geotechnical Engineering, Journal of Earthquakes in South China, and Journal of Rock Mechanics and Geotechnical Engineering. He received the Outstanding Graduate Award of Peking University in 1983, the Canadian Government Laboratory Fellowship in 1992, the Mao Yi-Sheng Soil Mechanics and Geotechnical Engineering Youth Award in 2006, the Outstanding Young Researcher Award from China National Natural Science Foundation in 2007, the Excellent Contribution Award from the International Association for Computer Methods and Advances in Geomechanics in 2008, Excellent Paper Award from the 2011 Annual Conference of the Geological Society of China, and Outstanding Award from the Journal of Rock Mechanics and Geotechnical Engineering in 2012.

Cause and Mechanism of Fatal Zhenxiong Landslide of January 11, 2013

Z. Q. Yue[*#1]
[1]Department of Civil Engineering, The University of Hong Kong, Hong Kong, China
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The fatal Zhaojiagou landslide suddenly occurred in a dry season in the early morning of January 11, 2013 in Zhenxiong County, Yunnan Province, southwestern China. The failed colluvium slope had an overall dip angle 20° and occupied a volume 2.1×105 m^3 of about 16 m thick, 110 m long and 100 m wide. The soil and rock mixture debris was rapidly deposited over the front gentle slope area of 650 m long and 250 m wide. The overall slope angle from the back scarp crest to the debris deposition toe was about 19°. The Zhaojiagou village of 16 houses was located over a plane area of 10,000 m^2 at 500 m to 650 m horizontal distances to the failed slope toe. A large amount of the debris rapidly arrived and instantly buried 14 village houses with 46 people, 59 pigs and 5 cattles. The thickness of the debris deposition over the village was up to 13 m thick. This paper presents an independent investigation result of the landslide and found its cause possibly due to a sudden eruption of highly pressurized natural gas accumulated and stored in the deep ground of the failed slope. A literature review has shown that this gas cause of fatal landslides was not yet reported in open literature available in English and Chinese. The finding would be useful to landslide hazard reduction and prediction in the region and around the world.

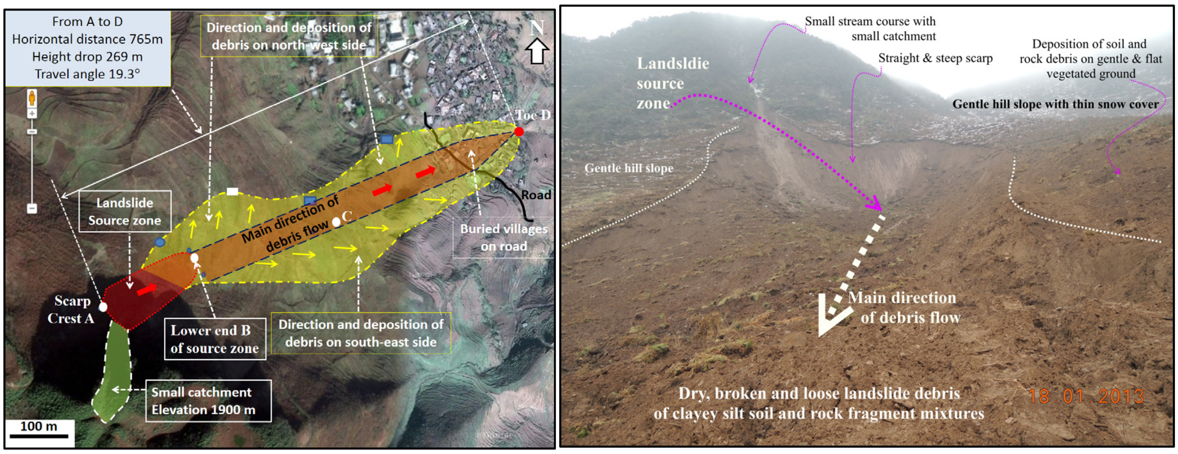

Figure 1. Plan view (a) and source zone of Fatal Zhenxiong Landslide of January 11, 2013.

Acknowledgements

The NSFC grant (No. 41372336) is acknowledged.

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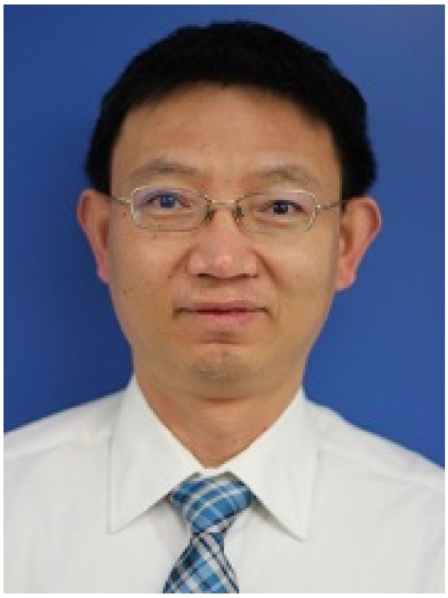
Theme Lecture 8



Professor Jian Deng
Department of Civil Engineering, Lakehead University, Thunder Bay, Ontario, Canada

Theme Lecture Title

A Critical Analysis and Stabilization of Nipigon River Landslide in Ontario, Canada

Dr. Jian Deng is currently an invited researcher in the Centre for Excellence for Sustainable Mining and Exploration of Canada and an assistant professor in the Department of Civil Engineering at Lakehead University, Canada. Dr. Deng holds Bachelor's degree, Master's degree, and PhD degree in Mining & Geotechnical Engineering. Prior to joining Lakehead, he worked for Feng Copper Mine, Central South University in China, the University of Waterloo, and WCR Consulting Inc. in Canada, and had over 15 years' research, education, and industry experience. He is a licensed professional engineer (P.Eng.) in Canada. Dr. Deng is the author/co-author of more than 60 referred publications on the topics of Stochastic Dynamics, Structural Reliability, and Dynamic stability of structures in the areas of Mining and Geotechnical Engineering. One of the papers has been cited 146 times in Google/scholar as of Sept. 20, 2016.

A Critical Analysis and Stabilization of Nipigon River Landslide in Ontario, Canada

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Presenter: Jian Deng, Andrew Farina

This paper presents a case history study on the geologic investigation and numerical modelling of a landslide in the area of Nipigon River, northwest of Ontario, Canada, to determine the causes of the landslide that occurred in 1990 and to identify the failure mechanism. The landslide occurred on the east bank of the Nipigon River, north of the Town of Nipigon. The landslide involved approximately 300,000m^3 of soil and extended almost 350m inshore with a maximum width of approximately 290m. It caused significant environmental and economic impacts. Since then, progressive landslides along the river banks have occurred from time to time. In this study, the failure probability of further landslides in this area is assessed by using the Monte Carlo simulation method in the GEO-SLOPE software. Stabilization measures have been designed to mitigate further slides, and to support a proposed country road on the river bank (Fig. 1). The environmental impact of the landslide is also discussed.

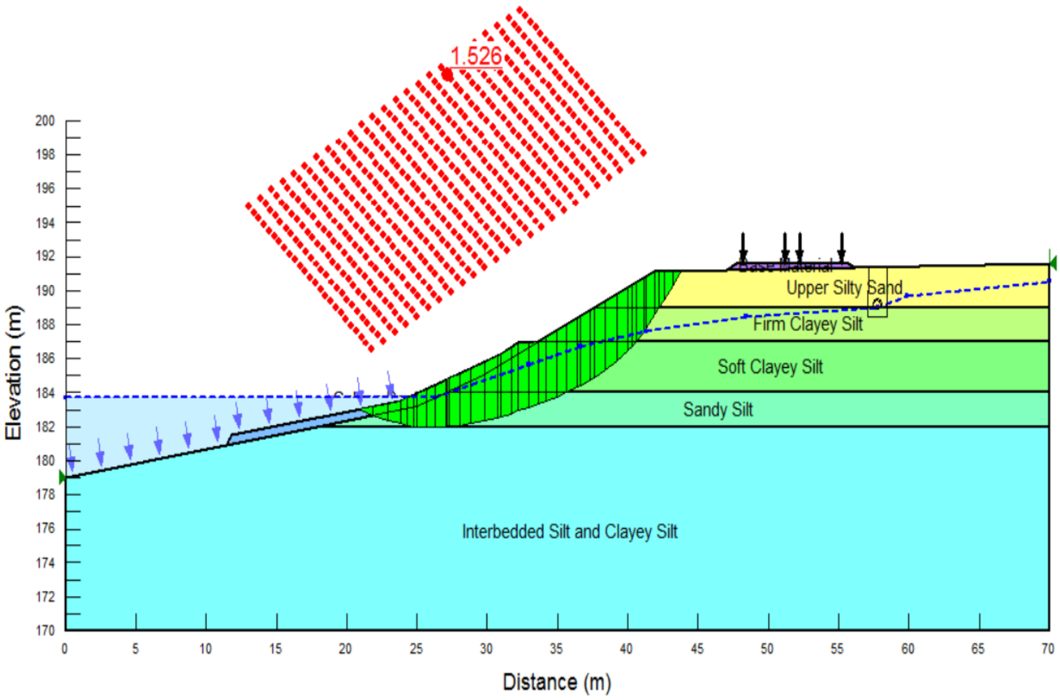

Figure 1. Slope stability analysis with reduced water table and gabion baskets

Theme Lecture 9

Professor Xing-min Meng
College of Earth and Environmental Sciences, Lanzhou University, China

Theme Lecture Title

Effectiveness of Debris Flow Mitigation Strategies in Mountainous Region

Dr. Xingmin Meng is a professor in Physical Geography, College of Earth and Environmental Sciences, Lanzhou University, China. He worked in UK universities for 21 years as researcher and lecturer between 1991 and 2012. He served as the Dean of School of Arid Environment and Climate Change, Lanzhou University between 2010 and 2015. Since then, he has been serving as the Dean of the School of International Exchange, Lanzhou University, and the Director of the Centre of Environmental Geology and Geohazards of Gansu Province, China. His main research interests are in geohazards monitoring, early warning and prevention. He is recipient of the awards including the National Outstanding Scientist award from the Science and Technology Association of China in 2014.

Education

1980-1984: Bachelor in Geology, Changan University, Xian, China

1992-1998: Ph.D in Geography, Royal Holloway, University of London, United Kingdom

Professional Experience

1984-1985: Assistant Lecturer, Department of Geology, Changan University, China

1985-1991: Research Associate, Geological Hazards Research Institute, Gansu Academy of Sciences, Lanzhou, China

1991-1992: Research Assistant, Department of Geography, University of Leicester, United Kingdom

1992-2012: Research Associate, Lecturer, Department of Geography, University of London, United Kingdom

2010-present: Professor, College of Earth and Environmental Sciences, Lanzhou University, China

Research field

Geohazards Monitoring, Early Warning and Prevention

Effectiveness of Debris Flow Mitigation Strategies in Mountainous Region

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Debris flows represent major hazards in most mountainous regions of the world where they repeatedly result in disasters. Traditionally, debris flows are controlled using civil engineering structures such as check dams (Jakob and Hungr, 2005; Chen SC and Wu CY, 2014). However, such mitigation works may induce a false impression of safety and sometimes amplify the scale of environmental hazards such as the catastrophic debris flow in 2010 in Zhouqu county, China. Therefore, other methods such as the use of vegetation as an eco-engineering tool are increasingly being adopted. Given such a contrary situation and, in order to explore much more effective mitigation works to control debris flows in the mountainous regions, the selected Sanyanyu and Goulinping debris flows are described and comparatively analysed as typical cases from Gansu province, China, one with check dams and one without. Numerical simulations are carried out to assess the effect of the check dam at the lower part of the Sanyanyu gully and Goulinping gully. An argument based on hypothesis and facts from positive and negative aspects is summarised. The increased soil cohesion provided by the root development of three monospecific stands of Robinia Pseudoacacia of different ages growing within the debris valley, and on a larger scale, their effects on channel morphology are assessed. The results show that the inappropriate mitigation measures (check dams) that have commonly been applied in the region are questionable, the stability provided by vegetation (Figure 1) could result in a less active valley system and that overall the development of debris-controlling vegetation could make a major contribution to ecosystem restoration. It is concluded that channel works and ecological methods combined together are probably preferred approaches to minimize the debris flow damage in debris flow catchments characterised with high mountains, concentrated rainfalls and active nontectonic movement.

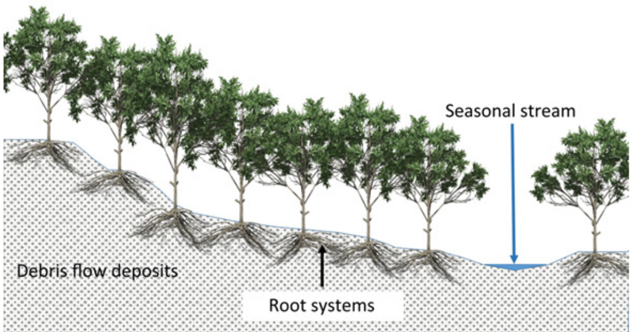

Figure 1. Root networks of vegetation on the debris flow deposits.

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Theme Lecture 10

Professor Ying-fa Lu
School of Civil Architecture and Environment, Hubei University of Technology, Wuhan, China

Theme Lecture Title

Mechanism and New Stability Analyses of Progressive Failure of the Thrust-type Landslide

Professor Yingfa LU earned a bachelor's degree in the Department of Engineering Mechanics of Xi'an Jiaotong University and a doctorate in the Civil Engineering Department from University of Sciences and Technologies of Lille in France. His research interests mainly cover rock and soil mechanics, geo-technical engineering, slope stability, natural disaster monitoring and prediction, foundation engineering. He has proposed a new theoretical system of progressive deformation and failure mechanism and five new calculating methods of safety factor of slope. He has proved that the perfect elasto-plastic model is not suitable for describing the progressive failure process of slope, and the yield limit stress and peak stress spaces of geo-materials are changed with the damage evaluation. The proportional yield limit stress and peak stress are decreased with the damage development for most geo-materials. A generalized constitutive model is suggested to describe the complete process properties of stress (or load) and strain (or displacement) of rock-soil mass. The classification of different stability zone (stable zone, less stable zone, critical state and un-stable zone) along sliding face is proposed. It is found that both the shear stress and strain are discontinuous in the un-stable zone. A new calculating method (sliding face boundary method) is suggested to describe the discontinuous characteristics. A failure angle rotation method of originality is proposed to search for the potential sliding face of soil slope. Till now he has published more than 80 research papers in journals related to this subject.

Mechanism and New Stability Analyses of Progressive Failure of the Thrust-type Landslide

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The theories of progressive deformation failure of thrust-type landslide are established in this study. The failure mechanism, mode and control standard are proposed, and a critical state is defined. A new shear stress model (NSM) is proposed to describe the mechanical behaviors of the complete process of geo-materials. The four methods (Comprehensive sliding resistance method, Main thrust method (MTM), Comprehensive displacement method (CDM), Surplus displacement method (SDM)) of stability evaluation of landslide are suggested. The curve between the monitoring displacement and time is described for the different points on the sliding surface. The numerical results show that MTM, CDM and SDM are feasible to evaluate the slope stability.

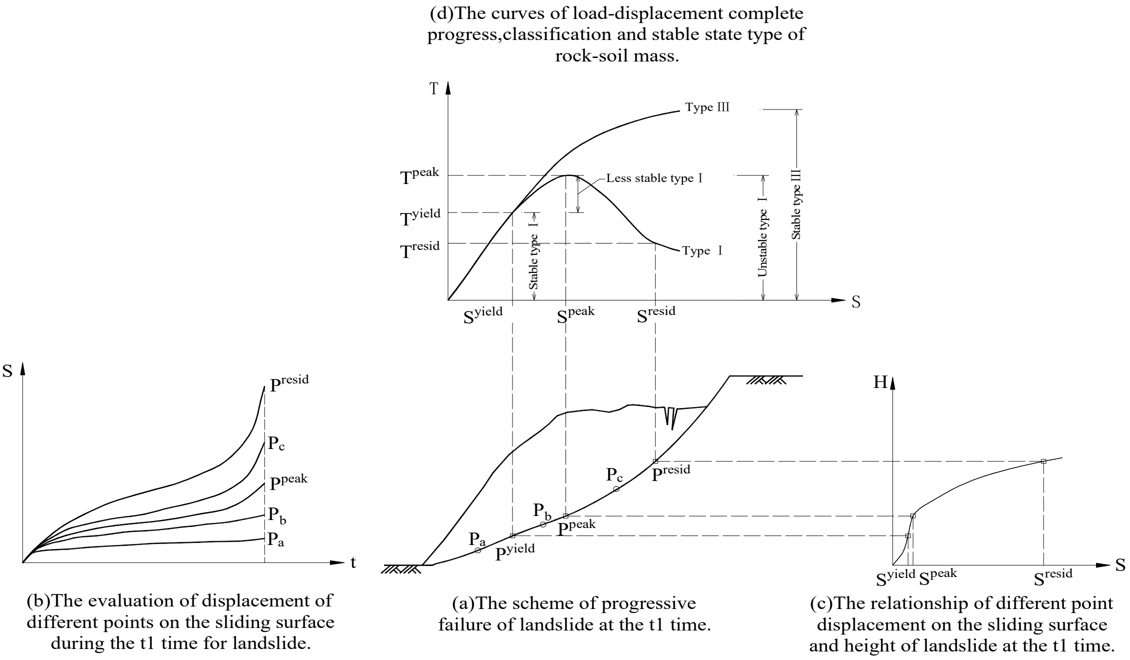

Figure1. The relationship among deformation, time and height of landslide and rock-soil classification for the thrust-type landslide.

Acknowledgements

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Theme Lecture 11

Professor Yang Ju

State Key Laboratory of Coal Resources and Safe Mining, China University of Mining & Technology, Beijing, Beijing, China

Theme Lecture Title

Numerical Analysis of Failure Processes in Soil-Rock Mixtures Using Computed Tomography and 3D Particle Flow Code Models

Dr. Ju is a Cheung Kong Distinguished Professor in Mining and Geotechnical Engineering issued by the Ministry of Education of China. He has been granted the National Natural Science Fund for Distinguished Young Scholars of China. He has received the special government allowance of Chinese State Council and been selected for the National Key Talents Support Programme. He has published two academic books and more than 120 peer-reviewed research papers. He has won the National Natural Science Award (Second Class), the Natural Science Award issued by the Ministry of Education three times (First Class).

Education:

September 1985 to July 1989, Bachelor's Degree, Civil Engineering, Qingdao University of Technology, Qingdao, China

September 1989 to March 1992, Master's Degree, Civil Engineering, Harbin Institute of Technology, Harbin, China

September 1992 to November 1995, Ph.D, Civil Engineering, Harbin Institute of Technology, Harbin, China

May 2008 to June 2012, Ph.D, Applied Mechanics, University of Calgary, Calgary, Canada

Professional Experience:

From November 1997 to May 2002, Vice Director, Institute of Rock Mechanics and Fractal geometry, China University of Mining and Technology, Beijing, China

From June 2002 to May 2006, Vice Dean, School of Mechanics and Civil Engineering, China University of Mining and Technology, Beijing, China

From June 2006, Executive Director, State Key Laboratory of Coal Resources and Safe Mining, China University of Mining and Technology, Beijing, China

Research interests:
1. Damage mechanics and failure criteria for geomaterials
2. 3D reconstruction methods for discontinuous structures of geomaterials
3. Numerical methods in geomechanics and applications to mining and geotechnical engineering
4. Visualization methods for discontinuous structures and dynamic stress fields of geomaterial and reservoirs

Numerical Analysis of Failure Processes in Soil-Rock Mixtures Using Computed Tomography and 3D Particle Flow Code Models

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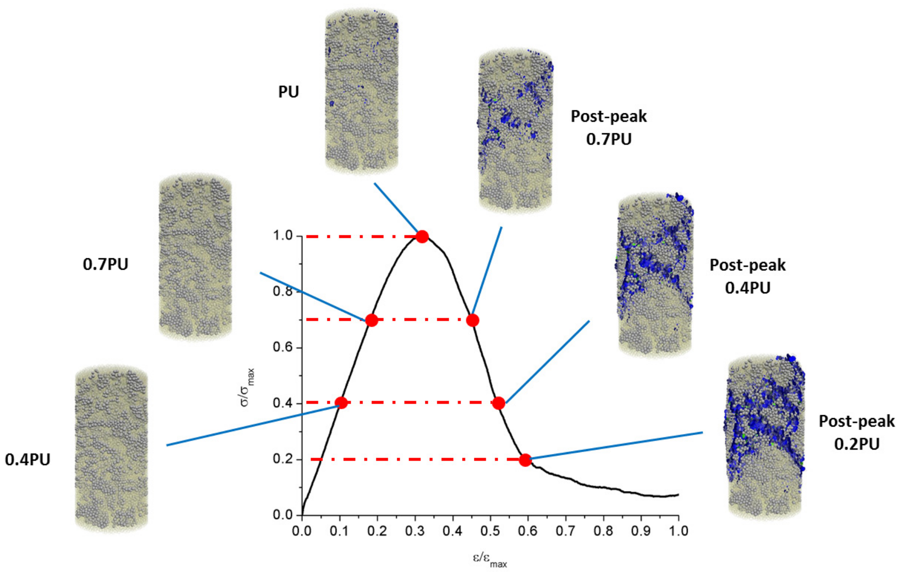
Abstract:

Soil-rock mixture (SRM) is a unique type of geomaterial characterized by heterogeneous composition and complicated structure. Accurate characterization and prediction of the mechanical properties of SRM using continuum-based soil and rock mechanics theories is intractable. This study reports a novel numerical method incorporating microfocus computed tomography (μCT) and three-dimensional particle flow code (3D PFC) to probe SRM deformation and failure processes. Construction of three-dimensional (3D) PFC models allowed the complex structures of SRM to be represented. Through simulation of the entire failure process in PFC3D, data on SRM strength, elastic modulus and crack growth were obtained. The influence of the rock ratio on SRM strength, deformation and failure processes, as well as its internal mesoscale mechanism, was analysed. Comparison of simulation results with experimental data verified the good agreement between 3D PFC models and prototype SRM in terms of structure, compression process, deformation, and failure patterns. The intrinsic meso-mechanism of SRM failure can be effectively analysed using 3D PFC models.

Keywords: Soil-rock mixture (SRM); PFC3D model; Three-dimensional structure; Microfocus computed tomography (μCT); Failure mechanism; Crack growth.



Simulation results of the failure patterns of SRM at various loading stages

Fluid Transport in Extensively Fractured Rocks

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The geomechanical behaviour of rock masses can be influenced by pore fluids that can exist at various scales within the fabric of the rock. Poromechanical behaviour of the rock is important in examining coupled influences of the porous fabric and the saturating fluid (Selvadurai, 2007; Yue and Selvadurai, 1995). The evolution of the porous fabric with the development of damage is important to many problems in rock mechanics. The nature of damage development in rocks can be complex and several theories base on damage mechanics concepts have been adopted to describe the evolution of permeability and elasticity properties that ultimately describe the poromechanical response (Mahyari and Selvadurai, 1998; Selvadurai and Shirazi, 2004; Selvadurai, 2004; Pellet, 2009). A further aspect of damage evolution is the transition of the damaged region to an extensively fractured rock mass. In this situation, the rock can develop a fragmented structure that can significantly alter the fluid transport characteristics within the rock mass, which in turn can influence the stability of rock masses. The conventional treatment of fluid transport in fractured rock masses largely focus attention on the fluid transport characteristics of single fractures and its evolution particularly with the application of normal stresses (Nguyen and Selvadurai, 1998; Selvadurai and Yu, 2005; Selvadurai, 2015). This paper presents the results of a research investigation where an argillaceous rock is subjected to failure and permeability tests are performed to evaluate the bulk axial permeability of the rock in the failed configuration. It is observed that the gross fracture development can lead to a four orders of magnitude increase in the permeability of the intact rock. This has implications to the assessment of ground water flow into excavation damaged zones in tunnels and at the base regions of slopes and deep excavations that are triggering zones for landslide activity.

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Theme Lecture 13

Dr. Jian-bo Zhu
Department of Civil and Environmental Engineering, The Hong Kong Polytechnic University, Hong Kong, China

Theme Lecture Title

Replicating Brittle and Hard Rocks Using 3D Printing with Applications to Rock Dynamics and Crack Propagation

Dr. Jianbo ZHU is an Assistant Professor of Rock Mechanics and In-Charge of Rock Mechanics Laboratory at the Hong Kong Polytechnic University. He got his PhD degree from Swiss Federal Institute of Technology (EPFL) in 2011. Before coming to Hong Kong, he was a Postdoctoral Scholar at California Institute of Technology (Caltech). His research interests include rock dynamics, rock caverns and injection induced earthquakes. He has authored over 50 papers including over 20 in international journals. In 2011, he was awarded the Fellowship for Prospective Researchers from Swiss National Science Foundation. He is a member and Editorial Board and Guest Editor of Rock Mechanics and Rock Engineering journal (Springer). He also served as member of Rock Dynamics Commission of International Society for Rock Mechanics, Rock Dynamics committee, Protective Engineering Committee and Underground Engineering Committee of Chinese Society of Rock Mechanics and Engineering, and Council of the Institute of Materials, Minerals and Mining (Hong Kong Branch).

Education

- Sichuan University, China
  Master, Geotechnical Engineering, 2008 (Heping Xie)
  Bachelor, Hydraulic and Hydro-Power Engineering, 2005
- Swiss Federal Institute of Technology (EPFL), Switzerland
  Ph.D.,Mechanics, 2011 (Jian Zhao)
- California Institute of Technology, US
  Postdoctoral Scholar, 2012-2013 (Ares Rosakis, Nadia Lapusta)

Research interests:

- Rock dynamics
- Rock cavern
- Injection induced earthquakes

Replicating Brittle and Hard Rocks Using 3D Printing with Applications to Rock Dynamics and Crack Propagation

J. B. Zhu*#1 and T. Zhou[1,2]

[1]Department of Civil and Environmental Engineering, The Hong Kong Polytechnic University, Hong Kong, China
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In this study, we explored the replication of natural rocks using a superior 3DP material and subsequently utilizing the 3DP replicated rocks for mechanical and fracturing behaviour studies. First, static uniaxial compression tests were conducted to identify the most suitable 3DP material from ceramic, gypsum, PMMA (poly methyl methacrylate), resin (accura® 60) and SR20 (acrylic copolymer) for mimicking rocks. Our experimental results showed that the 3DP resin produced via stereolithography (SLA) was the best for mimicking rocks, although its brittleness needs to be improved. Subsequently, three methods, i.e., freezing, incorporation of internal macro-crack and addition of micro-defects were proposed to enhance the 3DP resin's brittleness. Second, we adopted the micro-computerized tomography (micro-CT), 3D reconstruction and SLA techniques to replicate rocks with identical micro-structures (Figure 1). Static and dynamic tests were, subsequently, performed on these artificial rocks to study their mechanical and fracturing behaviours. The tests data showed that the mechanical properties, i.e., dynamic strength and Poisson's ratio, the fracturing process and failure patterns of the resin-based 3DP rocks were similar to those of the natural rocks. Lastly, the influences of the pre-existing flaws and loading types on the mechanical properties and 3D crack growth of the 3DP resins were studied. The results revealed that the flaw geometries greatly affect the axial strain and compression strength of the 3DP resins. 3D crack growth was more complex in static loading than that in dynamic loading.

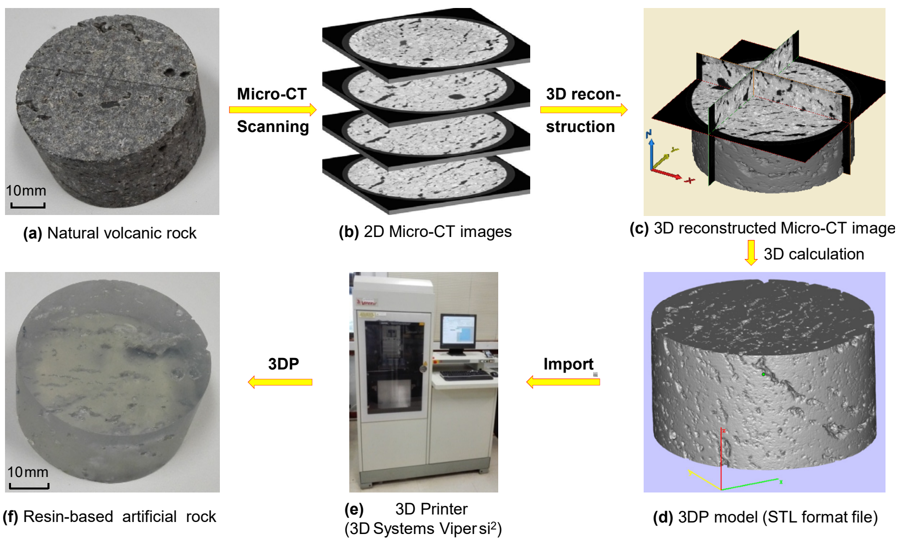

Figure 1. Workflow of producing resin-based artificial rock samples.

Theme Lecture 14

Professor Hong-tian Xiao
Department of Civil Engineering & Architecture, Shandong University of Science & Technology, Qingdao, China

Theme Lecture Title

Analysis of Crack Problems in Graded Halfspace Subject to Complex Loading

Dr. Hongtian Xiao is a professor of Shandong University of Science & Technology Since 2001. He got a Ph.D. degree from Tsinghua University in 1998. He served as the head of Underground Engineering during 2012 to 2016. His main research interests are in numerical analyses in geotechnical engineering and fracture mechanics for graded materials. He has published 2 books and 64 journal papers. He is recipient of the awards including the outstanding young scientists from Chinese Association of Rock Mechanics and Rock Engineering (2002).

Education:
September 1980 to June 1984, Bachelor of Engineering, Mining Engineering, Shandong University of Science & Technology, Tai-an, China
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September 1994, Ph.D., Hydraulic Engineering, Tsinghua University, China

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From November 1997 to October 2001, Associate Professor, College of Resources and Environmental Engineering, Shandong University of Science & Technology
From November 2001, Professor, College of Civil Engineering & Architecture, Shandong University of Science & Technology
From July 2004- June 2006, Post-doctoral fellow, Department of Civil Engineering, The University of Hong Kong

Research field:
1. Numerical analyses in geotechnical engineering
2. Fracture mechanics for graded materials

Analysis of Crack Problems in Graded Halfspace Subject to Complex Loading

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In general, all solid materials can be considered as non-homogeneous because their properties can vary with location in the three-dimensional space. One special type of solid material is characterized by the variations of its physical and mechanical components, structures and properties along only one given coordinate; the material properties have very small or no variations in any other direction perpendicular to the given coordinate. These types of solid materials are called graded materials.

The boundary element method (BEM) is now firmly established in many engineering disciplines and is increasingly used as an effective and accurate numerical tool. Fracture mechanics has been the most active, specialized area of research in BEM. In the past 15 years, we have used the fundamental solution of a mutlilayered elastic solid to develop a new type of BEM and analysed the fracture mechanics in layered and graded solids.

In this paper, we examine the fracture mechanics problem of cracks embedded in a graded half-space. The half-space is subject to complex loading on the external surface. Two novel numerical methods and the superposition principle in fracture mechanics are employed for the analysis of the crack problem. The numerical methods are based on the fundamental solution of a multilayered elastic medium and are, respectively, applied to calculate the stress fields of a graded half-space without cracks and the discontinuous displacements of crack surfaces in a graded half-space. The stress intensity factor (SIF) values are calculated using discontinuous displacements and the influence of material properties and crack positions on the SIF values is analysed. Using the minimum strain energy density criterion and the SIF values, the minimum values of the strain energy density factor are calculated and the crack growth is analysed. Results show that the heterogeneity of graded media exerts an obvious influence on the fracture properties of cracked graded elastic solid.

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Theme Lecture 15

Mr. U Kar Winn
Geomotion (Singapore) Pte Ltd, Singapore

Theme Lecture Title

Stability Analysis of Geology Structures Controlled Tunnel Profiles

Mr. U Kar Winn received his B.Sc (Geology) from Rangoon Arts & Science University, Myanmar in 1976, M.Sc. (Geotechnical Engineering) and M.Sc. (International Construction Management) from Nanyang Technological University, Singapore in 1999 and 2005 respectively. In Myanmar, he worked as research assistance in Applied Geology Department after his graduation. Then he works as an Exploration Geologist with Myanmar Oil Corporation and Myanmar Shell B.V. He migrated to Singapore in 1993 and worked with various companies till now. He has published some technical papers on Residual Soils of Singapore, Pressure-meter testing & interpretation methods, Deep Excavation Practices of Singapore and Jurong Rock Cavern Projects.

Education:
B Sc. (Geology), Yangon University, Myanmar, 1977
M Sc. (Geotechnical Engineering), Nanyang Technological Univ., Singapore, 1999
M Sc. (International Construction Management), N T U, Singapore, 2005
Part Time Ph D Candidate, NTU, Singapore (2013-2020)

Professional working Experience:
2016-Present: GEOMOTION (SINGAPORE) PTE LTD, formerly GeoLS Pte td : Sr. Project Manager / Professional Geologist
2014-2015: Presscrete Engineering P/L : Principal Geotechnical Engineer
2009-2014: SINTEF-TRITECH-MULTI CONSULT (Project management Team, Jurong Rock Cavern Project: Sr. Principal Geologist
2009: Worley Parsons (Singapore) : Senior Geotechnical Engineer
2004-2009: Sembawang Engineers & Constructors P/L (formerly Semb Corp E & C): Principal Geotechnical Engineer
2001-2004: ST Architects & Engineers P/L : Engineering Geologist
1993-2001: Soil & Foundation P/L : Senior Geotechnical Engineer (Singapore)
1978-1993: Myanmar Shell B.V and Myanmar Oil & Gas Enterprise, Myanmar

Research field:
1. Soil mechanics & rock mechanics
2. Underground rock cavern construction and Tunnelling
3. Numerical analyses in geotechnical engineering
4. Geotechnical site investigation
5. Geotechnical Instrumentation

Stability Analysis of Geology Structures Controlled Tunnel Profiles

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[1]GeoLS Pte Ltd, Singapore
[2]Department of Earth Sciences, The University of Hong Kong, Hong Kong
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Traditionally arch-roofed style was designed for tunnels and caverns due to the smooth stress distribution which resulted stable condition. However, flat-roofed profiles are unavoidable for excavation in low-angle bedded sedimentary rocks, horizontally foliated metamorphic rocks, and nearly horizontally jointed and fractured isotropic rocks.

In a recently completed underground hydrocarbon storage project in Singapore, caverns were excavated in nearly horizontally-bedded sedimentary Jurong Formation of late Triassic to early Jurassic age. Those flat roofed tunnel profiles, which are controlled by geological structures, are observed stable after application of 80 mm thick shotcrete and 4 m long fully grouted GFRP bolts (Figure 1).

In the analytical stability analysis, special consideration such as Voussoir beam theory design procedure based on systematic iterations developed by Diederichs and Kaiser (1999) was adopted. Sufficient horizontal stress ratio (σ_H:σ_h:σ_v = 2.2 : 1.8 : 1.0) and beam thickness (minimum 0.35 m) are the main factors contributing to the stability of flat roofed tunnel profiles. The stability was counter-checked by a numerical analysis using the two-dimensional FEM RS^2 program (Rocscience Inc, 2010) (Figure 1).

The average monitored vertical displacement was stable at about 3 mm throughout the excavation period, which agreed with those obtained by the RS^2 numerical analysis.

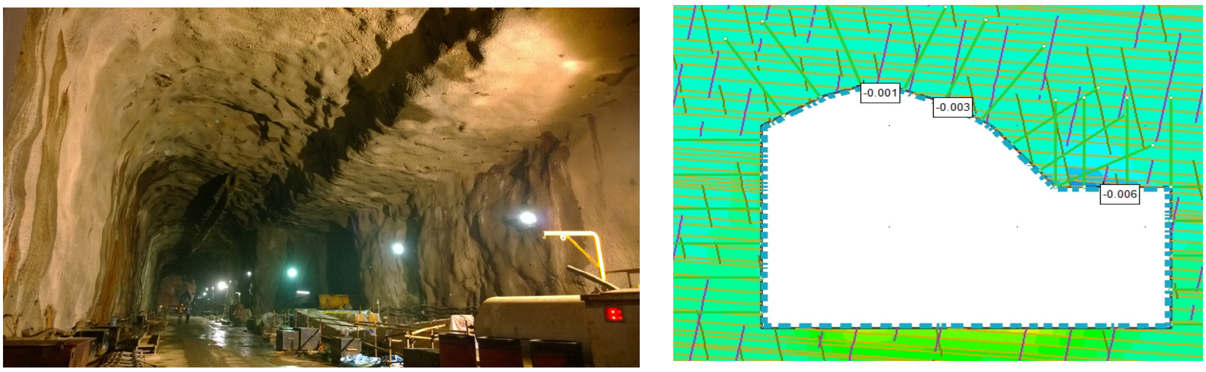

Figure 1. (left) Tunnel section showing flat roof with right angled shoulders (16 m wide, 12.3 m high), (right) Calculated vertical displacement (m) after tunnel support application analysis with RS^2 FEM program.

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Theme Lecture 16

Professor Jian-xi Ren
College of Architecture and Civil Engineering, Xi'an University of Science and Technology, Xi'an, China

Theme Lecture Title

Failure Law of Surrounding Rock of Rectangular Crossheading at Fully-Mechanized Caving Face in Deep Thick Coal Seams and Its Repair Support Technology

Professor Jian-xi Ren earned a bachelor's degree in civil engineering from Xi'an Institute of Mining in China and a doctorate in geotechnical engineering from the Wuhan Institute of Rock and Soil Mechanics of Chinese Academy of Sciences in China. He is a Vice Dean of School of Architecture and Civil Engineering, Xi'an University of Science and Technology. He was born in 1968. He has won one first prize, four second prizes, one third prize from Provincial Awards of Advancement on Science and Technology. He has published 100 research papers, 3 monographs and 3 textbooks. Out of these papers, there are 3 papers retrieved by SCI,18 papers by EI. His research majors are supporting technology of surrounding sock of coal mine road, the rock damage mechanics and the real-in-time CT testing of rock meso-damage characteristics.

Failure Law of Surrounding Rock of Rectangular Crossheading at Fully-Mechanized Caving Face in Deep Thick Coal Seams and Its Repair Support Technology

J. X. Ren*[1], J. L. Sun#[1], K. Zhang[1], J. Wang[1], D. Y. Liu[1] and D. X. Wang[1]
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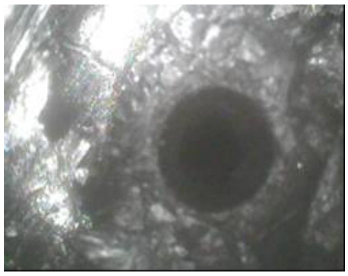
Rectangular crossheading has been widely used in the modern large coal mines because its bigger and effective using space which is convenient for the transportation of lager coal machinery. But the phenomenon of stress concentration has occurred easily at the four corners of rectangular crossheading. Because of the influence of the rock stress, mining influence, characteristic of surrounding rock and groundwater, deformation often occurred in the rectangular crossheading and the failure laws are very complicated. So the study for rectangular crossheading at fully-mechanized caving face in deep thick coal seams has important significance.

The study is based on the rectangular crossheading of 40101 working face in Hujia River coal mine which is burial at a depth of 600 m. The results show that the main failure mode include asymmetrical deformation, roof caving, anchor cable failure and bolt tensile failure. The roof failure can be divided into three kinds: abscission layer and deflection failure, shear failure and extrusion and rheological failure. The main failure of crossheading mode includes compression and shear failure, sliding instability, splitting failure and transverse arch failure.

Because of the severe failure of the rectangular crossheading, the present supporting scheme can not ensure the safe production of coal mine. The new repair supporting scheme is urgently needed. Based on the results of failure mode, failure laws and the measurement of broken rock zone (Figure 1), using the combined arch theory to design supporting scheme, and based on the optimization principle of depressurization, reinforced support and yielding pressure, the paper presents the supporting scheme of rectangular crossheading at fully-mechanized face in deep thick coal seams. The results of FLAC numerical simulation and industrial test site shows that the new supporting scheme is reasonable and effective which can control the deformation of rectangular crossheading surrounding rock.

(a) Roof

(b) Left working slope



(c) Right working slope

Figure 1. The measurement of broken rock zone.

Theme Lecture 17

Professor Wei-guo Liang

College of Mining Engineering, Taiyuan University of Technology, China

Theme Lecture Title

Experimental Study of Glauberite Salt Rock Creep under Compression and Dissolution Coupling Effect

Professor Weiguo Liang graduated from Taiyuan University of Technology, P. R. China and obtained his Bachelor of Mining Engineering in 1994 and Doctor of Engineering in 2004. From 2004 to 2007, he ever worked in Rock and Soil Mechanics Institute, China Academy of Sciences as a postdoctoral fellow. As a visiting professor, he ever worked in University of Waterloo under supervision of Professor Maurice Dusseault for one year from 2005 to 2006. From 2011 to 2016, he was the Dean of College of Mining Engineering, Taiyuan University of Technology. He is a Vice-President of TYUT at present.

Professor Liang is a gainer of National Outstanding Youth Foundation of China, a person selected as the National Ten-thousands Talents Project, a winner of the National Excellent One Hundred Doctoral Thesis, a New Century Excellent Talent of Ministry of Education of China, and a China Youth Science and Technology Award winner.

Professor Liang has been engaged in research and teaching of Rock Mechanics and Mining Engineering for 20 years, mainly on mechanical behaviour of salt rock and solution mining. In recent year, as a leader of the research group of In-situ Modification of Rock Properties for Improved Mining, Professor Liang and his group are engaged in pyrolysis extraction for shale oil and gas, coal bed methane recovery by replacement and driving with CO_2 injection, et al.

Experimental Study of Glauberite Salt Rock Creep under Compression and Dissolution Coupling Effect

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To investigate the creep mechanical properties of glauberite salt rock, tri-axial creep tests were conducted under the influence of 4MPa confining pressure and 5MPa axial pressure with infiltration pressure of 3, 2 and 1 MPa, respectively. The creep process of glauberite salt rock was divided into four stages: hydraulically connected creep,creep with pore water pressure, creep after drainage and creep with 20MPa axial pressure in order to simulate processes of solution mining. Creep behaviors of these four stages were studied by comparative analysis.

The results show that hydraulic connection time for galuberite salt rock is longer with decrease of infiltration pressure. At hydraulically connected creep stage and creep stage with pore water pressure,continual dissolution of the minerals and the effective stress have signifacant effect on creep deformation of specimens. The deformations of glauberite salt rock at creep stage after drainage and creep stage with 20MPa axial pressure are dominated by the softening degree of mechanical properties of solid skeleton caused by loading history of infiltration pressure and dissolution effect. With larger infiltration pressure, the soften degree inside glauberite salt rock caused by dissolution is more serious, then creep strain and average strain rate are relatively larger. At last, the generalized Kelvin model is used to fit creep curves at different stages, and it can describe tri-axial reep deformation behavior of glauberite salt rock under dissolution and infiltration pressure coupling effect. This study not only reveals creep behavior of glauberite salt rock under compression and dissolution coupling effect, but also provides references for stability analysis of glauberite deposits in the process of solution mining.

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Theme Lecture 18

Professor Jian-jun Liu
School of Geoscience and technology,
Southwest Petroleum University, Chengdu,
China

Theme Lecture Title

Mechanism of Casing Damage and Control Method in Daqing Oil field

Professor Jian-jun Liu got a bachelor's degree in mining engineering, a Master degree in engineering mechanics from Liaoning Technical University, and a PhD degree in fluid mechanics in the University of Chinese Academy Sciences in 2001. Liu is a principal professor in geological engineering of Southwest Petroleum University, executive chief editor of Petroleum journal and Journal of Southwest Petroleum University (Science and Technology Edition). He is also a Changqing Scholars Distinguished Professor of Wuhan Polytechnic University. His research fields cover the porous flow, multi-field coupling in geosystem, oil field geological disaster prevention, computational fluid dynamics and heat transfer. He has published more than 240 peer-reviewed papers in journals and conference proceedings, and 5 monograph publications.

Mechanism of Casing Damage and Control Method in Daqing Oil Field

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Casing damage in oil field is a tough technology problem, which has caused huge economic losses. The comprehensive research methods of combining theoretical, numerical, experimental studies and field data analysis were used to reveal the casing damage mechanism and try to find control method. The relevant research results and engineering practices in recent 10 years show that the casing damage causes include both engineering factors and geological factors. For Daqing oil field, the casing failure mechanism can be briefly divided into three categories from mechanics: tensile failure, shear failure and extrusion failure. The interaction between porous flow field and geostress field is the main reason, which causes geostress evolves during oil field development and may lead to stress concentration near wellbore. During water flooding exploitation process, pressure difference, fault sliding and mudstone immersion is direct cause of tensile, shear and extrusion failure respectively. Numerical simulation results and field application cases show that controlling block pressure difference, optimization of well pattern arrangement can effectively improve the geostress distribution state and decrease the ratio of casing damage well.

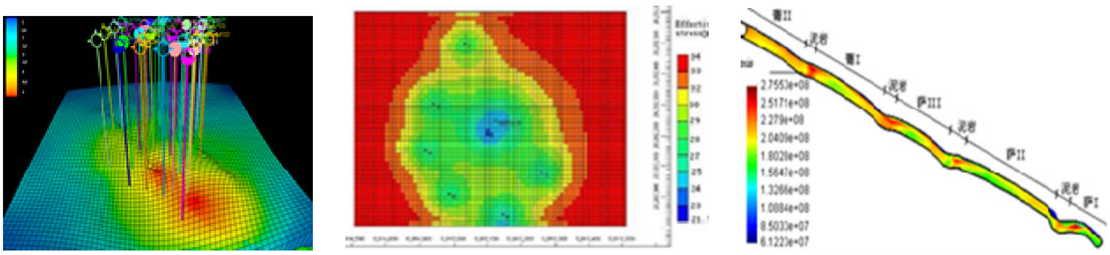

Figure.1 Synchronous calculation results of seepage field, stress filed and casing stress

Acknowledgements

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Theme Lecture 19

Professor Chang-fu Wei
State Key Laboratory of Geomechanics and Geotechnical Engineering, Institute of Rock and Soil Mechanics, Chinese Academy of Sciences, Wuhan, China

Theme Lecture Title

Constitutive Model of Chalk with Considering Effect of Intergranular Physicochemical Forces

Dr. Changfu Wei is a professor of Institute of Rock and Soil Mechanics, Chinese Academy of Sciences since 2006. He received his Ph.D. degree from the University of Oklahoma (USA) in 2001. He served as the Vice Director of the State Key Laboratory of Geomechanics and Geotechnical Engineering since 2008 to present. His main research interests are in the physics and mechanics of multiphasic porous media, Constitutive modelling of unsaturated soils, subsurface flow and transport processes and fully-coupled analysis of multiple physical and chemical processes in multiphasic porous media.

Education:
September 1984 to July 1988, Bachelor of Engineering, Hydrogeology and Engineering Geology, Hefei University of Technology, Hefei, China
September 1988 to July 1991, Master of Science, Solid Mechanics, Institute of Rock and Soil Mechanics, Chinese Academy of Sciences, Beijing, China
December 2001, Ph.D., Civil Engineering, University of Oklahoma, Norman, USA

Professional Experience:
From August 1991 to August 1997, Research Associate, Institute of Rock and Soil Mechanics, Chinese Academy of Sciences, China
From January 2002 to January 2004, Research Associate, University of Oklahoma, USA
From February 2004 to January 2006, Research Assistant Professor, University of Vermont, USA
From February 2006 to present, Professor, Institute of Rock and Soil Mechanics, Chinese Academy of Sciences, China (2008-present, Vice Director, State Key Laboratory of Geomechanics and Geotechnical Engineering, Wuhan, China)
From July 2010 to present, Adjunct Professor, Department of Civil Engineering and Architecture, Guilin University of Technology, Guilin, China

Research field:
1. Physics and mechanics of multiphasic porous media
2. Constitutive modelling of unsaturated soils
3. Subsurface flow and transport processes
4. Fully-coupled analysis of multiple physical and chemical processes

Constitutive Model of Chalk with Considering Effect of Intergranular Physicochemical Forces

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Chalk is a high-porosity, poorly cemented soft rock, which can be viewed as a type of electrically-charged porous media with multiphase and multispecies (Rises et al., 2005). One of the salient features of chalk is its sensitivity to the chemistry (say composition and concentration) of the saturating fluids. Pronounced physicochemical interactions can occur between the solid matrix of chalk and the pore fluids, so that the chalk shows strong chemo-mechanical coupling effect and intricate mechanical behavior. Previous studies have shown that different compositions and concentrations in the injected brine, as well as the activities of brine species can significantly influence the stability of rock. In this talk, we explore the water-weakening mechanisms of chalk, based on the fundamental principles of thermodynamics and poromechanics. In this context, we theoretically show that the effects of chalk-water interactions can be conceptually combined into a macroscopic stress, i.e., the generalized osmotic pressure. We also show that the true pore water pressure in the chalk can be significantly different from the measured or the applied water pressure, and that such a discrepancy stems from the effects of capillarity and adsorption as well as osmosis, providing new insights into modelling the chalk-water interactions. Explicit formulations are developed for the intergranular stress and the generalized osmotic pressure, with consideration of the effects of capillarity, adsorption and osmosis. Then a conceptual constitutive model for chalk is proposed to explain the effect of the aqueous chemistry on the mechanical behavior of chalk. The proposed model is validated by comparing the theoretical calculations with the experimental results, showing that the model is capable of addressing the compaction problem of chalk reservoir during the replacement of oil by seawater in the pores.

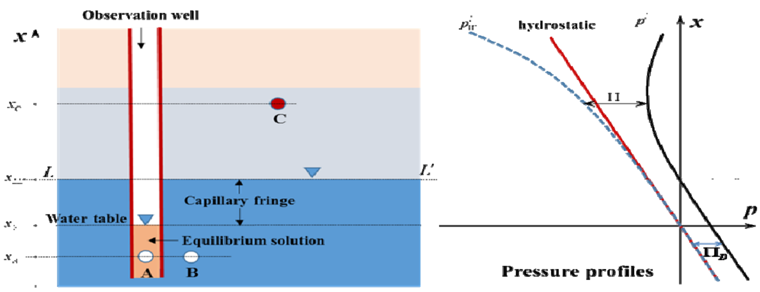

Figure 1. Schematic illustration of osmotic phenomena.

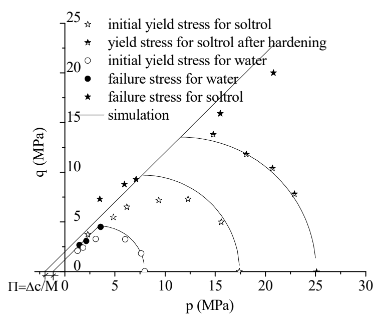

Figure 2. Yield and failure surfaces of chalk respectively in soltrol and water saturated samples.

Theme Lecture 20

Professor Jianfu SHAO
Laboratory of Mechanics of Lille, University of Lille, Villeneuve d'Ascq, France
HOHAI University, Nanjing, China

Theme Lecture Title

A Micro-mechanics based Elastic-Plastic Model for Saturated Porous Rocks

Professor SHAO has received his doctoral degree in 1987from University of Sciences and Technologies of Lille in France. He is currently an excellent-class professor at this university. He was the director of the Laboratory of Mechanics of Lille (2010-2013), a Changjiang chair professor at Wuhan University (2007-2010), an overseas expert for the Chinese Academy of Sciences (CAS). He received an overseas outstanding young investigator award from the NSFC and the CAS. Since 2010, he is Thousand-talent chair professor at HOHAI University. Ha has received an "excellent contributions Award (2011)" from the Int. Association for computer methods and advances in Geomechanics (IACMAG).

Professor Shao has developed a series of theoretical, experimental and numerical studies in mechanics of geomaterials. He and his team have brought significant contributions to various topics, in particular, mechanics of saturated and partially saturated porous materials, damage mechanics and plasticity, thermo-hydromechanical and chemical coupling. He is an international expert on multi-scale approaches to nonlinear behaviors and THM-C coupling. His research results have been widely applied to various engineering applications such petroleum industry, geological disposal of nuclear waste and sequestration of acid gas, hydraulic power engineering. He was and is a principal investigator of more than thirty national and international projects in in France and in China.

He is author and co-author of 185 peer-reviewed SCI journal papers. He has also edited three books and contributed to 16 collective books.

He is an editorial member of four top-level international journals (IJP, IJRMMS, COGE, NAG) and an associated editor of the European Journal of Environmental and Civil Engineering (EJECE).

A Micro-mechanics Based Elastic-plastic Model for Saturated Porous Rocks

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In this paper, a micro-mechanics based elastic plastic model is developed for a class of porous rocks. The rock is considered as a porous medium composed of a solid matrix and spherical pores. The solid matrix obeys a pressure sensitive plastic criterion. The effective elastic properties of the porous rock are determined from a linear homogenization scheme. The macroscopic plastic criterion is deduced from a limit analysis method. The obtained macroscopic criterion explicitly depends on the porosity. Further, in order to describe poromechanical coupling, a generalized effective stress concept is adopted for the description of plastic behaviour of the saturated porous rock. The expression of effective stress is also issued from a micromechanical analysis and depends on both pore pressure and plastic properties of the solid matrix.

The proposed elastic-plastic model is implemented in a computer code and applied to describe mechanical responses of typical porous rocks in both drained and undrained conditions. Comparisons between experimental data and numerical results are presented for different loading paths. Effects of initial porosity and its evolutions are evaluated. Influences of effective stress are also analysed. An example of results is presented in Figure 1.

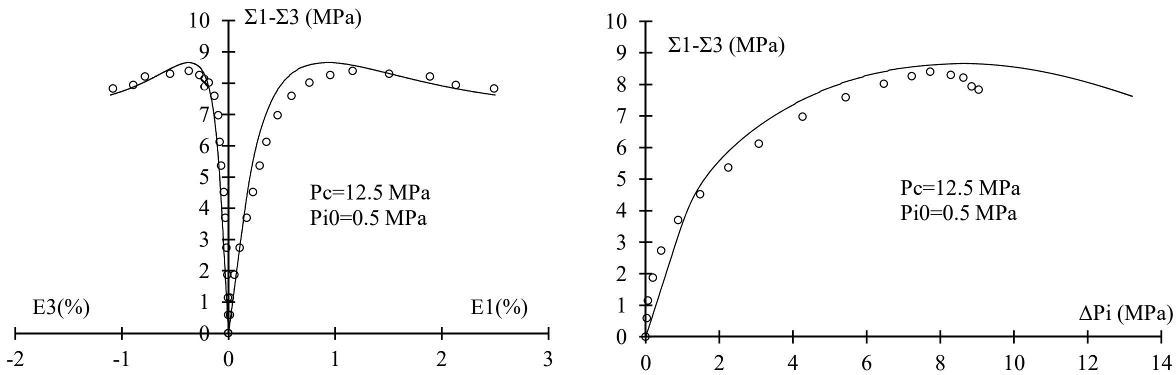

Figure 1. Stress-strain curves (left) and pore pressure (right) of a chalk in an undrained triaxial compression test.

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Theme Lecture 21

Professor Xiaoping Zhou
Chongqing University
Chongqing, China

Theme Lecture Title

Numerical Simulation of Initiation, Propagation and Coalescence of Cracks in Rocks Using General Particle Dynamics

Professor Zhou has received his doctoral degree in 2000 from Chongqing University. He is Changjiang Scholar professor at Chongqing University. He received China national funds for distinguished young scientists.

Professor Zhou has developed a series of experimental and numerical studies in rock mechanics. He and his team have brought significant contributions to the numerical methods, the strength criterion, reliability theory and the constitutive laws. His research results have been widely applied to various engineering applications, such as slope engineering and underground engineering.

He is author and co-author of 85 peer-reviewed SCI journal papers. He has also edited two books.

Numerical Simulation of Crack Growth and Coalescence in Rock-like Materials Containing Multiple Pre-existing Flaws Using General Particle Dynamics

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A novel meshless numerical method, which is called general particle dynamics, is proposed to simulate samples of rock-like brittle heterogeneous material containing four pre-existing flaws under uniaxial compressive loads, the numerical simulations are conducted to investigate the initiation and growth and coalescence of cracks by using a General Particle Dynamics code(GPD). An elasto-brittle damage model based on the extension of the Hoek-Brown strength criterion is applied to reflect the initiation, growth and crack coalescence and the macro-failure of the rock-like materials. The pre-existing flaws are simulated by empty particles. The particle is killed when its stresses satisfy the Hoek-Brown strength criterion. Then, growth path of cracks is captured through the sequence of such damaged particles. A statistical approach is applied to model the rock-like material heterogeneity. It is found from the numerical results that the samples containing four pre-existing flaws may produce five types of cracks at or near the tips of pre-existing flaws including wing crack, coplanar or quasi-coplanar secondary cracks, oblique secondary cracks, out-of-plane tensile cracks and out-of-plane shear cracks. It is also observed from the numerical results that four coalescence modes are observed, the tensile mode (T); the compression mode (C); the shear mode (S); and the mixed tension/shear mode (TS). A higher load is required to induce crack coalescence in the shear mode (S) than that for crack coalescence in the tensile mode (T) and mixed mode (TS). It is concluded from the numerical results that crack coalescence occur following the weakest coalescence path among all possible paths between any two flaws. The numerical results are in good agreement with the reported experimental observations.

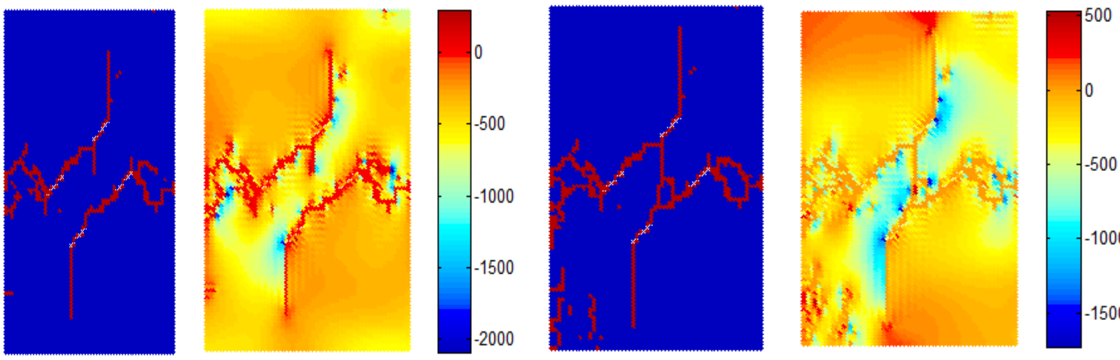

Figure 1. The numerical simulation of crack coalescence of rock-like sample (c=0mm, α=45°) under uniaxial compressive loads

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Theme Lecture 22

Professor Lansheng Wang

Chengdu University of Technology,
NSKLGP, Chengdu, China

Theme Lecture Title

The Diexi Paleo-Dammed Lake at Upstream of Mingjing River, Sichuan, China

Professor Wang is an emeritus Professor of Chengdu University of Technology. He was born in 1934 in Hangzhou, Zhejiang Province, China. He graduated in Hydrological and Engineering Geology from Beijing University of Geology in 1957. He was a lecturer at this university for two years. Since September 1959, he has worked at the Chengdu University of Geology (at present, Chengdu University of Technology). From 1981 to 1984, he was a visiting scholar at Istituto Sperimentole Modelli e Strutture (ISMES) in Italy. His research interests include unstability problem of rock mass and epigenetic time-dependent structure. His book publications include *Analysis Principle for Engineering Geology*, *On Stability of Bank Slopes around the Three Gorges of Yangtze River*, *Epigenetic Time-Dependent Structure and Human Engineering*, and *High Geostress Field and Unstability Problem of Surrounding Rock for Erlangshan Highway Tunnel*.

The Diexi Paleo-Dammed Lake at Upstream of Mingjing River, Sichuan, China

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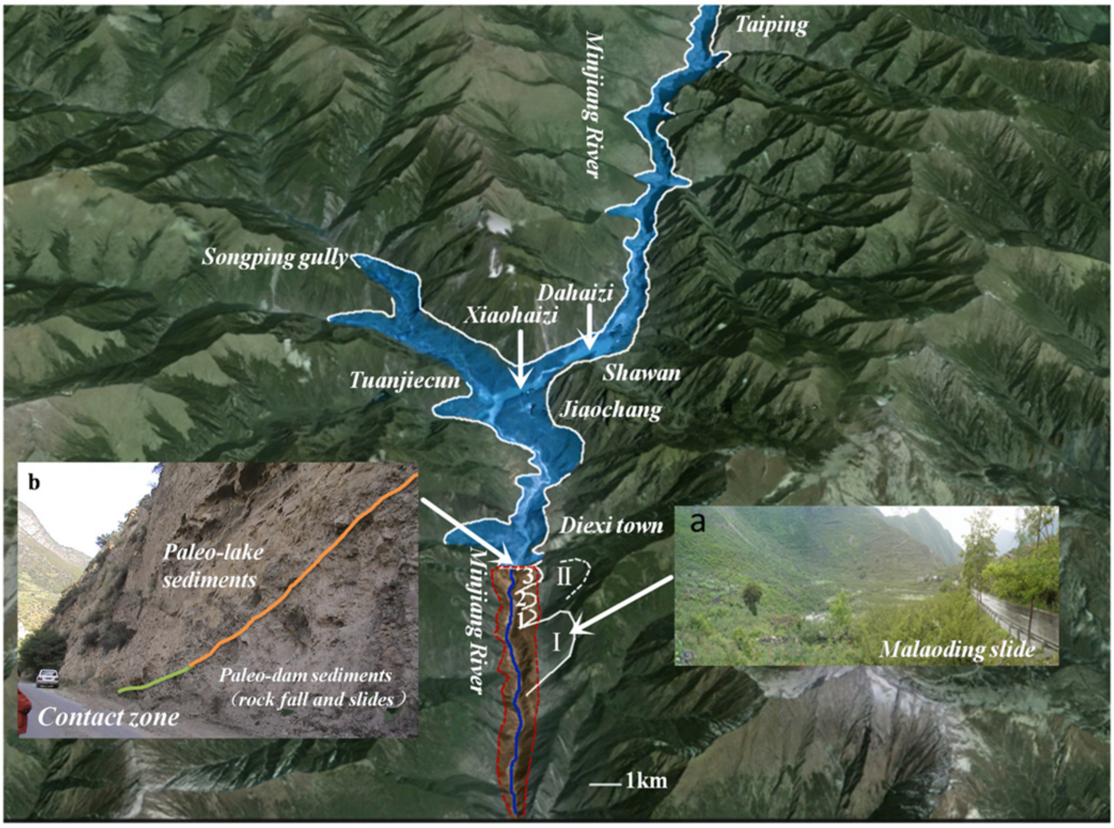
A huge ancient landslide-dammed lake at the upstream of the Mingjiang River has been discovered in 1999, which came into being 30000 yeas ago. It existed for ten thousand years with over 240m thick lacustrine sediments formed. It existed for ten thousand years and disappeared with its outburst in 15000 years ago. After that several other such lakes and their sediments been founded in the same area. We further demonstrate its formation and disappearance using whole cross-section cores, 14C dating, pollen analysis, stable carbon-oxygen isotopes, organic matter content and particle sizes. Paleo-seismic and paleo-climate information from drill cores reveal that the dammed-lake experienced at least 10 strong earthquake from 30830 aB.P.to 14854 aB.P. The change has a certain correlation with climate change. The findings from this new approach and investigation are a basis for the ancient topography and paleo-climate evolution in the upper reaches of Mingjiang River.



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Long-term Performance of Large Longyou Caverns Manually Carved in Argillaceous Siltstone Ground

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The Longyou rock caverns were carved about 2000 years ago at shallow depths in argillaceous siltstone in Longyou county of Zhejiang Province, eastern China. They have large spans and locate at extreme shallow-buried depths. The group of more than 24 caverns can be divided into two sub-groups according to their portal entrances. As shown in Figure 1, the first sub-group has a vertical portal entrance and the second has a horizontal portal entrance. Field investigation results indicate that the first sub-group has much better long-term performance that the second sub-group. The first sub-group has at least ten large rock caverns of complete stable and integrity. All the second sub-group have failed and their roofs are collapsed. The totally different long-term performance of the two sub-group caverns can be due to the facts that the vertical portal entrance can make the cavern fully infilled with water while the horizontal portal entrance can only make the cavern partially infilled with water. The full water infilling in the first sub-group can protect the rock caverns in stable and integral conditions. The partial water infilling in the second sub-group cannot prevent the rock cavern roof rocks from collapse by gravity.

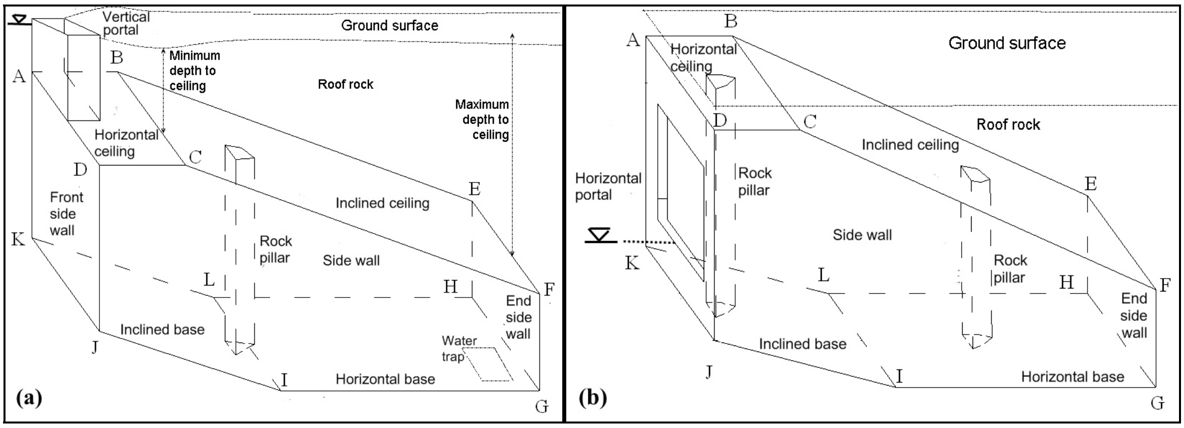

Figure 1. Two types of Longyou caverns: (a) vertical portal entrance; (b) horizontal portal entrance.

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Characteristics on Rock Fractures Induced by Different Excavation Methods of Deep Tunnels

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The seven long tunnels of Jinping II hydropower station are deeply buried. Several specific experimental tunnels with different overburden and geometric sizes were excavated at this site. Digital bore-hole camera, micro-sliding meters, cross-hole acoustic wave equipment and acoustic emission apparatus were adopted. This paper will introduce the synthetic in situ experimental methods through pre-installed facilities and pre-drilled boreholes. Typical properties of the surrounding rock mass, including cracks, deformation, elastic wave and micro fractures, were measured during the whole process of the tunnel excavation. The characteristics on rock fracture formation and evolution in tunnels EDZ were analysed under different construction methods involving of TBM and drilling and blasting, the pilot tunnels were driven by full-face and different benches. The relationships between EDZ and tunnel geometry size, overburden and excavation method were described as well.

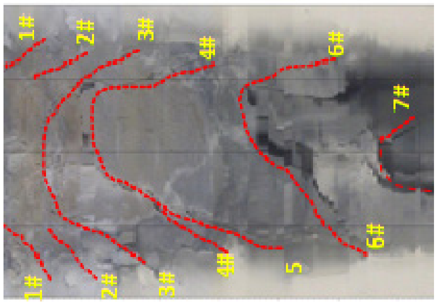

Figure 1. Fractures observation during tunnel excavation.

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Impact Analysis of Tunnel Cross Section Shape on Tunnel Temperature Field Calculation

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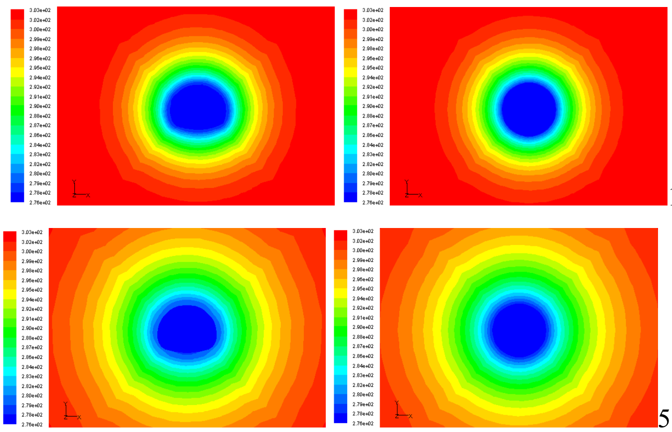
Most traffic tunnels have horseshoe shape or side wall shape cross sections. Calculation formulae of temperature field for circular cross section tunnel model were studied by many scholars. It is necessary to find out the difference of temperature distribution between circular cross section tunnel model and actual horseshoe shape cross section tunnel model. Thus, the temperature field of horseshoe shape tunnel and corresponding equivalent diameter circular tunnel are calculated under the same conditions by fluid dynamics software Fluent. The calculation results show that as the calculation time goes, the temperature difference of surrounding rock for horseshoe shape tunnel and the corresponding equivalent diameter circular tunnel is becoming smaller and smaller. The in-situ results of cold region tunnel temperature field have the same distribution law as the simulation results, and thus, at the long time tunnel operation stage, the circular section model can be used to calculate the temperature field instead of actual horseshoe cross section.



1 year

5 years

Figure 1. Radial temperature graph after calculated for 5 years (400m away from entrance section).

Acknowledgements

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Research on Deformation Rules of Surrounding Rock of the Shallowly-Buried Water Rich Loess Tunnel Influenced by Freezing-Thawing Circumstance

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Loess is a special kind of soil formed under the semi-arid climatic conditions, and it is widely distributed in the seasonal permafrost region of China. The influence of freeze-thaw action is particularly sensitive to the loess with high moisture content. In the construction of the shallowly-buried water rich loess tunnel, various types of disasters continue to occur due to the freeze-thaw cycle. In this paper, the No.1 loess tunnel located at Yangqu in Shanxi province was selected for research. The surrounding rock deformation rules and stability of the high moisture content tunnel were studied by micro analysis (Figure 1), laboratory experiment (Figure 2) and numerical simulation (Figure 3). The result shows that: the freezing and thawing cycles have an important influence on the mechanical properties of different moisture content, and hence the deformation, and even the stability of surrounding rock (Figure 4). Therefore, some protective measures such as anti-freezing and drainage should be taken to improve stability of the shallowly-buried water rich surrounding rock.

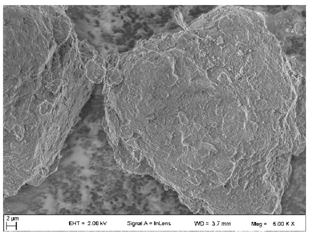

Figure 1. Analysis of microstructure of loess in Yangqu.

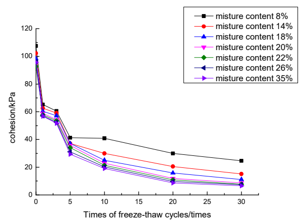

Figure 2. The influence diagram of the freeze-thaw cycle effect on cohesion of undisturbed soil.

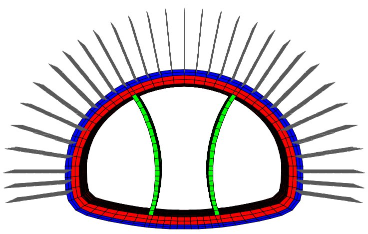

Figure 3. Tunnel supporting structure.

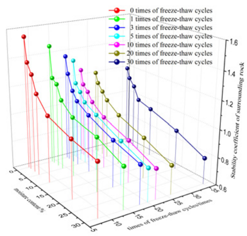

Figure 4. The stability coefficient of surrounding rock with different moisture content on the condition of different freeze-thaw cycles.

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Investigation of the Joint Yielding Mode of Segmental Tunnel Lining

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Over past years, the use of shield-driven tunnels at unfavourable conditions such as large diameters, high ground and water pressures, has increased considerably. In order to assess the actual structural capacity and safety level of concrete lining, the structural behaviour of segmental tunnel lining in Ultimate Limit State must be predicted and clarified. The objectives of this paper are to study the joint yielding mode of segmental tunnel lining with relatively weak interaction between adjacent rings. The mechanisms of joint yielding mode in segmental lining were traced and investigated by means of the proposed joint failure index (JFI) and segment failure index (SFI) approaches. Furthermore, the structural responses and associated phenomena of joint yielding mode were explained by mean of the Relative Flexibility Ratio (RFR) approach. It was shown that the mechanical behaviour and the failure history of segmental tunnel linings are influenced significantly by the rings interaction. For the type of joint yielding mode, the failure history and actual structural capacity of the linings are dominated by the segment joints. The joint yielding mode in segmental tunnel lining could be more dangerous for there is a lack of noticeable warning before failure.

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Detection and Analysis of Harmful Gas Emission in Hongyanxi Tunnel

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Hongyanxi tunnel is a long tunnel of Yonglong expressway. In the process of tunnel construction, harmful gases were detected. For comprehensively conducting the concentration and composition detection of harmful gas, classification of gas (shale gas or oil and gas) emission, gas source analysis and hazard assessments in Hongyanxi tunnel, etc., providing a basis for the prevention and control of harmful gas in the tunnel and the design of the tunnel project. In this paper, based on the analysis of the detection it analyzes and discriminants the causes of leakage and overflow light oil and natural gas meeting in the Hongyanxi tunnel formation and determines tunnel gas level, provide a technical support for tunnel prevention of harmful gases.

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Geological Structure and Mineralization Mechanism of Shale Gas in the Red Rock Creek Tunnel

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Red Rock Creek Tunnel is a long and large tunnel of Yonglong highway. After sorting through the geological structure and the mineralization mechanism of shale gas, we obtain the understanding in four aspects. In general, the geological structure of red rock creek tunnel is relatively simple, the change of tectonization will lead to joint fissure development and the fracture of rock mass. Karst tend to grow on the contact zone of soluble and non-soluble rock or unconformity surface. Shale matrix pore and fracture constitute the main reservoir space of shale gas, the crack provides a mi-gration path for the shale gas as well; the pore size can significantly affect its occurrence form. In the process of mineralization, shale gas authigenic constitutes the mechanism sequence from the absorption aggregation and the enrichment of expansion gap to piston-like movement or replace-ment migration.

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Improved Procedure for Determining Reaction Curve of Anchoring and Shotcreting Support in Circular Tunnel

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The mechanical behavior of anchoring and shotcreting support is analyzed using the convergence-confinement approach. A calculation procedure is presented which is able to provide the reaction curve of anchoring and shotcreting support by considering the composite stiffness which is related to the thickness of shotcrete lining and the anchored surrounding rock. The proposed procedure is a very useful tool for understanding the behavior of this widely used support and making full use of the self-support ability of the surrounding rock mass. Finally, theoretical results and actual engineering data are compared.

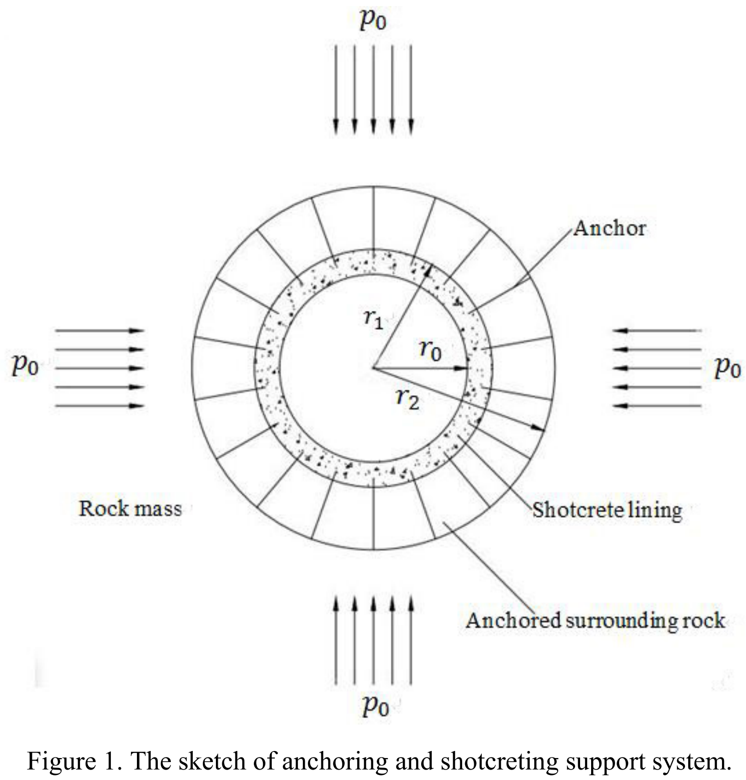

Figure 1. The sketch of anchoring and shotcreting support system.

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Reliability-Based Design for Rock Tunnel Stability Using Inverse-Reliability Approach

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The stability evaluation of rock tunnels, as one important geotechnical area dominated heavily by the unavoidable uncertainty, should be correctly implemented to produce meaningful designs. The conventional deterministic method does not explicitly and sufficiently reflect the uncertainty, where using a single value of factor-of-safety (FOS) may lead to the rock tunnel designs regarded as the misleading results. This fact makes for the tremendous development of the reliability method (through the reliability index or probability of failure) to consider the inherent uncertainty in a systematic manner. Currently, the design standards have an increasing tendency to guarantee rock tunnel stability by specifying a target reliability index. This reveals that the reliability level of a rock tunnel is pre-defined as a target to be satisfied. In this context and meanwhile due to a very wide acceptance of the FOS, an inverse-reliability approach (IRA) employing both the FOS and reliability index (i.e., a two-fold indicator strategy that uses the FOS and reliability index together) is proposed to deal with the stability assessment of rock tunnels. Such a technique can directly and flexibly calibrate the FOS, provided that the target reliability index has been given. On this basis, a surrogate model method is further presented considering the complicated nonlinear form of FOS involved in tunnel stability, where the Kriging model (KM) is used to obtain the explicit FOS-based performance function and then the adaptive Markov (AM) chain simulation is adopted to generate the sampling points. One typical tunnel example is provided to demonstrate the application of the proposed approach. Finally, several issues pertinent to the performance of our approach are also investigated. The developed approach associated with the calibration of FOS can be rationally done by not only incorporating uncertainties, but also satisfying a desired level of the prescribed reliability.

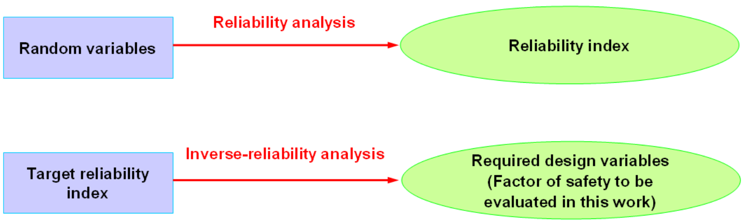

Figure 1. Comparison between reliability/inverse-reliability analyses.

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Effects of Defect Doping on Kaolinite (001) Surface with H_2O Adsorption

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Kaolinite is often a cause of deformation in soft-rock tunnel engineering, leading to safety problems. The mechanism of the deformation is closely related to the interaction between kaolinite and water molecules. In order to gain a better predictive understanding of the governing principles associated with this phenomenon, we investigated the adsorption of H_2O on the kaolinite (001) surface using the density functional theory at first. The results showed that the preferred adsorption sites on the kaolinite (001) surface for H_2O are the threefold hollow site with the adsorption energies ranging from 1.06 to 1.15 eV. H_2O does not adsorb on the six-fold hollow site of the aluminium (001) face of the third layer of kaolinite, implying that it is difficult for H_2O to penetrate the ideal kaolinite (001) surface. Because kaolinite has multiple defects, the effects of Mg, Ca, and Fe(II) doping on the adsorption and penetration of H_2O into the interlayer were studied systematically. The results showed that for the Mg-, Ca-, and Fe(II)-doped kaolinites (001), the surface relaxation around the doping layer changed from contraction to expansion, due to the redistribution of electrons. The adsorption energies of the H_2O monomer on Mg-, Ca-, and Fe(II)-doped kaolinites (001) were more than on undoped kaolinite (001). The results further revealed that the H_2O molecule can also absorb on the hollow site on the second-layer O surface of the Mg-, Ca-, and Fe(II)-doped kaolinites (001). For the undoped kaolinite, however, the H_2O molecule adsorbs on the surface only. The energetic barriers for penetration of H_2O from the adsorption site on the surface to the adsorption site on the O surface of Mg-, Ca-, and Fe-doped kaolinites were also calculated: 1.18 eV, 1.07 eV, and 1.41 eV, respectively. The results imply that the influences of Mg, Ca, and Fe(II) doping on kaolinite allow the adsorbed water molecules to penetrate from the on-surface adsorption site to the O-surface site.

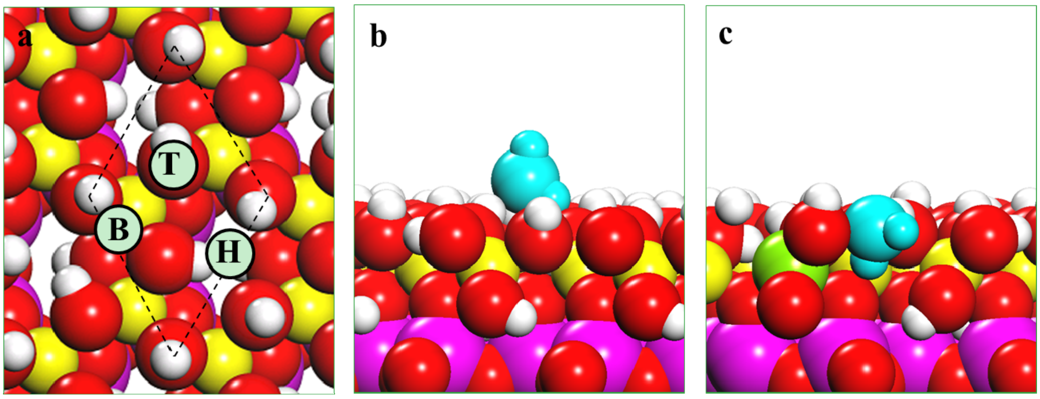

Figure 1. (a) Top view of kaolinite (001) surface with top (T), bridge (B), and hollow (H) adsorption sites; (b) Side view of an adsorbed water molecule on the surface hollow site of undoped kaolinite; (c) Side view of an adsorbed water molecule on the Al-surface hollow site of defect doped kaolinite.

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Three-Dimensional Dynamic Analysis of Quay Walls Based on PZC Mode

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Quay walls might be subject to severe damage due to seismic liquefaction. In most of the previous investigations for the seismic-induced dynamic response around quay walls have been limited to two-dimension cases. In this study, numerical simulation for earthquake response of quay walls was conducted by use of three-dimensional fully coupled finite element program SWAN3WAC. A generalized plasticity model, Pastor-Zienkiewicz-Chan, was adopted to analyze the dynamic behavior of saturated soil. Finite element procedure based on the u-p form of Biot equations was employed to perform the coupling analysis. The numerical results agree well with the observed records of quay walls, indicating that the SWAN3WAC procedure can be used to evaluate the dynamic response of quay walls.

Study on Mechanical Features of Brazilian Splitting Fatigue Tests of Salt Rock

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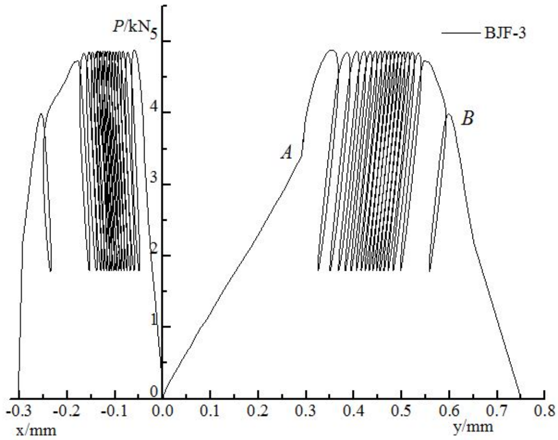
The microtest, SEM, was carried out to study the fracture surface of salt rock after the Brazilian splitting test and splitting fatigue test were carried out with a servo-controlled test machine RMT-150B. The results indicate that the deviation of using the tablet splitting method is larger than that of using steel wire splitting method. There are similar deformation features in both the conventional splitting tests and uniaxial compression tests. The stress-strain curves include compaction, elasticity, yielding and failure stage. Both the vertical deformation and horizontal deformation of splitting fatigue tests under constant average loading can be divided into " loosening - tightness - loosening " three stages, as shown in Figure 1. The failure modes of splitting fatigue tests under the variational average loading are not controlled by the fracturing process curve of the conventional splitting tests. The deformation extent of fatigue tests under variational average loading is even greater than that of conventional splitting test. The tensile strength of salt rock has relationship with crystallization conditions. Tensile strength of thick crystal salt rock is lower than the bonded strength of fine-grain crystals. In the figure 1, A and B is the starting and end point of cyclic loading, respectively.

Figure 1. Load-deformation curves of Brazilian split fatigue tests of constant average load



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Method for Describing Mesostructure of Heterogeneous Rock Material Based on Spatial Correlation Character

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According to the continuity for the natural rock, we propose a method for mesostructure of heterogeneous rock material based on spatial correlation character. Through introducing spatial correlation functions to represent the relevance of materials, the spatial correlation functions of rock-like materials are defined as (Tang et al. 2010, 2014) : $f(d) = e^{-\frac{d_{i,k}}{\Theta}}$; $d_{i,k} = |\boldsymbol{r}_i - \boldsymbol{r}_k|$, in which $d_{i,k}$ = distance between the centroids of element i and element k; $\boldsymbol{r}_i$ and $\boldsymbol{r}_k$ = position vectors of element i and k, respectively; Θ = a spatial correlation length factor. The heterogeneity described by the method is approaching to the actual heterogeneity of rock. The present method is incorporated into particle flow code (PFC), and a numerical model that can reflect rock's heterogeneity actually and efficiently is established. Taking Guangdong conghua granite for an example, the numerical models of PFC^{2d} and PFC^{3d} for actual mesostructure of granite are presented. A series of numerical simulations for Brazilian splitting tests and uniaxial compression tests are conducted, which are also compared with experimental tests respectively (Figure 1 and Figure 2). The simulation shows that the method describes the actual heterogeneity for rock, meanwhile, avoiding the complexity and low efficiency for the exiting digital image processing methods. Materials' spatial correlation character will affect its failure patterns apparently. The method provides an innovative way for the investigation on mechanical behavior of the rock-like heterogeneous materials.

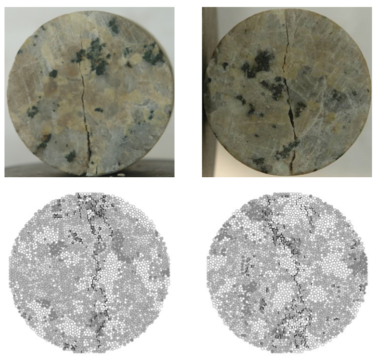
(a)
(b)


Figure 1. Failure patterns of samples under Brazilian splitting test (a) laboratory test (b) numerical simulation.

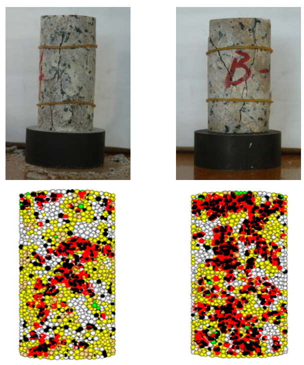
(a)
(b)


Figure 2. Failure patterns of samples under uniaxial compressive test (a) laboratory test (b) numerical simulation.

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Mode I-II Compression-shear Fracture Criterion for Non-contacting Crack of Rock-Like Brittle Materials

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In the practical project, structure fracture often undergoes a complex stress state. So studying fracture mechanism for mixed mode crack has important theoretical significance and practical value. Based on mixed-mode I - II crack and linear elastic theory, the geometrical characteristics and force form of crack are considered, the theoretical solution of the stress intensity factor (SIF) at the crack tip is introduced. The radial shear stress criterion and twin shear stress criterion suiting for mode II fracture are put forward. For I - II mixed-mode unclosed crack, this article presents a method to determine the fracture type by comparing the ratio of equivalent mode I and II SIF with that of mode I and II fracture toughness. In addition, an appropriate fracture criterion for mode I or II fracture is used to calculate the theoretical initiation angle. the compression-shear fracture test of the brittle rock-like samplems with single open pre-crack was carried out in compression, the theoretical initiation angles and the experimental results agree well.

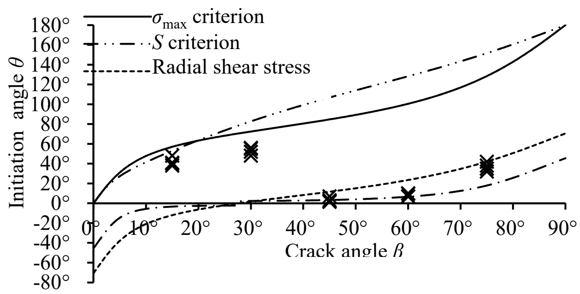

Figure 1. The comparison between theoretical and experimental fracture angle.

Acknowledgements

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Sand Grain Crushing under Multi-axial Loading Conditions

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Grain crushing is of great relevance to numerous important applications and processes in civil and mining engineering, ranging from pile installation and rock fall to mine comminution. The mechanism of grain crushing forms one of key microstructural origins underpinning a wide variety of complex phenomena in geotechnical engineering and mining industry, including yielding, deformation and failure. A good number of past studies have started to investigate the crushing behaviour of single sand grains. The crushing condition and fracture pattern have been thoroughly examined for grains subjected to uniaxial loading. In the context of geotechnical engineering, however, an individual sand grain is often in contact with several others and is more likely subjected to multi-axial loading conditions. This study presents a numerical investigation of the crushing process of a single sand grain under multi-axial loads based on peridynamics simulations. Peridynamics is a continuum based mesh free method extended from molecular dynamics and is capable to handle discontinuities including cracks. The grain is assumed to be perfectly elastic brittle with spherical shape. Our simulation results indicate that the critical failure load and fracture pattern of a grain under multi-axial loads differ significantly from those under uniaxial loading. They may depend on the number of loadings (coordination number) as well as the location of loading points. Based on the numerical results, we further examine the established stress-based failure criteria of single sand grain under multi-axial loadings, including the octahedral shear stress (OSS) criterion and maximum tensile stress (MTS) criterion. The MTS criterion can provide a more accurate prediction on the onset of crushing if a sound theoretical base can be established to solve for stresses in the sphere. The failure loads obtained from numerical models are compared with predictions using the two failure criteria. The findings from the study could offer insights into the behaviour of grain crushing which can be useful for future discrete modeling of granular sand where crushing is important.

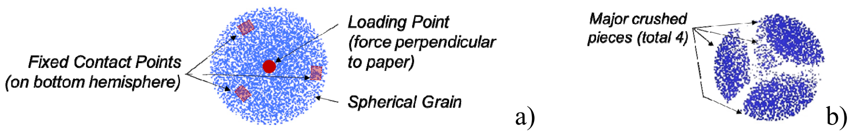

Figure 1. Numerical model of grain crushing with 4 contacts (a: model geometry, b: crushed pieces).

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Experimental Study on Dynamic Deformation of Unsaturated Granite Residual Soils

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Through laboratory custom dynamic triaxial experiments, the maximum dynamic elastic modulus of granite residual soils based on empirical formula in the conditions of suction-controlled and void ratio of 0.55 is obtained. The dynamic elastic modulus of unsaturated granite residual soil showed nonlinear attenuation along with increase of strain. The effect of net confining pressure on the dynamic stress and strain skeleton curves is stronger than the suction, when axial dynamic strain increased to about 0.2%, the dynamic elastic modulus of granite residual soil tended to be stable at the same suction condition. the maximum dynamic elastic modulus is shown as,

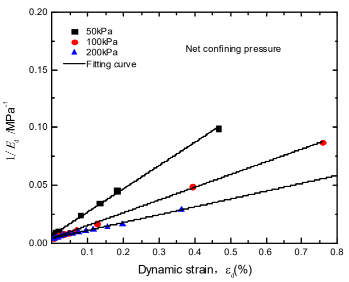

Figure 1. Dynamic elastic modulus of unsaturated granite residual soils under different confining pressure.

$$E_{max} = (5.7793s + 944.76)P_a(\frac{\sigma'}{P_a})^{0.448}$$

Acknowledgements

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Soil Responses under the Principal Stress Rotation

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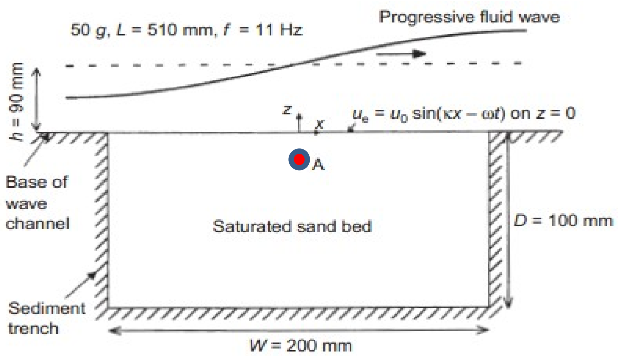
The principal stress rotation (PSR) occurs in many geotechnical engineering applications, such as under earthquake, wave and traffic loadings. The PSR can lead to the non-coaxiality and development of plastic strains. It can result in unsafe design without considering the PSR impact. The study first presents a soil PSR model, in which the PSR generating stress rate is separated from the total stress rate, and an independent hardening rule and flow rule are used for the PSR stress rate. The model is used to simulate responses of various types of soil in hollow cylinder tests under loadings with the PSR, and it indicates that the model simulations are in better agreement with the experimental results than the models without considering the PSR impact, especially in the simulations of liquefaction. The model is also implemented into the finite element method to simulate soil responses under wave and earthquake loadings. Its simulations are also in better agreement with centrifuge test results in these two boundary value problems than the models without considering the PSR impact.



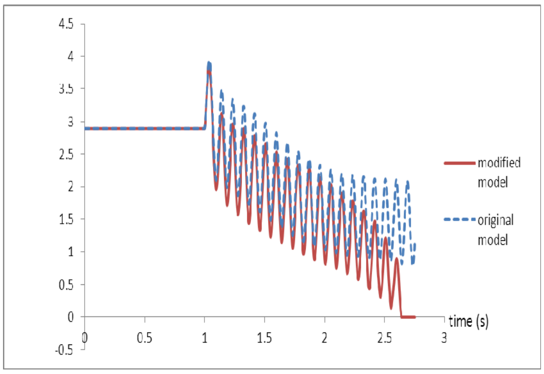


Figure 1. Simulation of Soil Responses under Wave Loading (a: Wave-Seabed Soil Interaction; b: Simulated Time History of Effective Vertical Stress with the PSR Model and Original Model at Point A)

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Multiscale Analysis of Asphalt Binder Fatigue Cracking

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Low temperature cracking in asphalt binder in winter has always been one of the most attractive problems for pavement engineers. In this paper, we present a new multiscale approach, which consists of dimensional analysis using Buckingham Π Theorem and J-integral analysis based on classic fracture mechanics, to evaluate the low temperature fracture on asphalt binder. Experiments including Direct Tension Test and Three Point Bending Test are conducted to verify the theoretical analysis. It is discovered that our theoretical analysis is in good agreement with experimental results, which provides a new perspective to analyze the asphalt low temperature cracking mechanism.

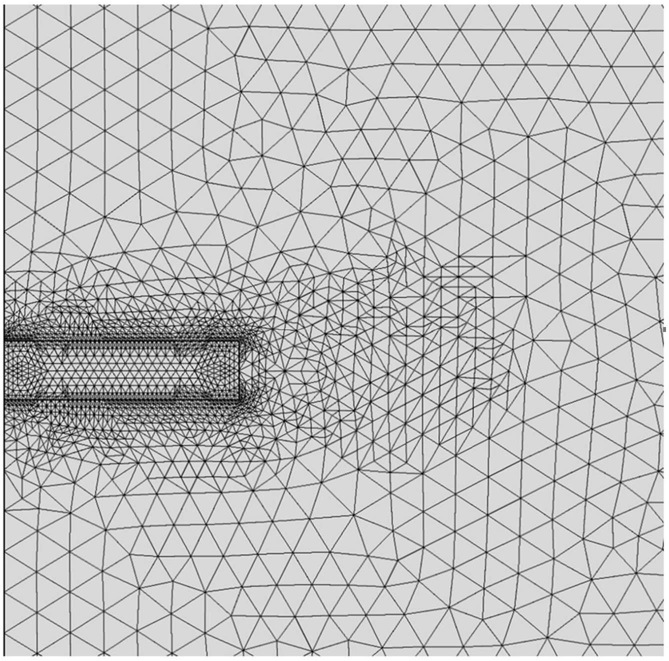

Figure 1. A magnified view of crack in asphalt binder.

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Numerical Study on THM Processes of EBS Experiment

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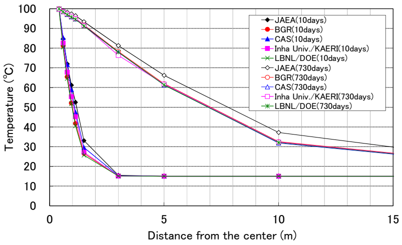
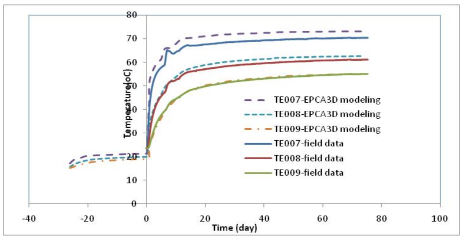
The work focuses on simulation of the in-situ full scale engineered barrier system (EBS) experiment conducted at the Horonobe URL in Japan using a self-developed numerical system, i.e. EPCA^{3D} (Pan, Feng et al. 2009, Pan and Feng 2013). Different materials, such as buffer material, concrete, sand layer, backfill and rock mass are considered in the modeling. Especially, the partially saturated medium for buffer material is considered by adding vapor flux terms to the water mass-balance equation. The cellular automaton technique is used to update all the state variables in the THM coupling. This study is part of the DECOVALEX-2015 project (2012-2015), which is the sixth in a series of development of coupled models and their validation against experiments (DECOVALEX) projects that were firstly established in 1992 by a number of national regulatory authorities and nuclear waste management organizations (Hudson, Jing et al. 2013). Six research teams are involved in the modeling of EBS experiment using their respective codes in the framework of DECOVALEX-2015 Task B2. This article presents a contribution of CAS (Chinese Academy of Sciences) research team for this task. A simplified 1D Model of Horonobe EBS experiment was firstly used to test the EPCA^{3D} code by comparing with other international research teams (Figure 1a). This is followed by a simulation of the full scale EBS experiment. The EPCA^{3D} simulations showed that the temperature, pressure and displacement evolution are well agreement with monitoring data (Figure 1b). The robustness of the EPCA^{3D} approach to such a complex THM coupling problem is demonstrated.



(a)



(b)

Figure 1 (a) Simplified 1D Comparison of the numerical modeling results on distribution of temperature and (b) comparison between EPCA^{3D} modeling and field data of full scale EBS experiment.

Acknowledgements

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Mechanism and Control Technology of Panel Roadway Floor Heave

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This paper is based on the actual conditions about the panel roadway floor heave in one coal mine in Huangling. The panel roadway floor heave mechanism is worked out by comprehensively utilizing the indoor test, theoretical analysis, numerical simulation and industrial test to carry out research for the panel roadway floor heave mechanism and control technology. Because of the comparatively high SiS_2 in the roadway floor mudstone and its soluble property in the construction water, the floor mudstone strength can be accordingly reduced. As a result, the squeezing and mobile floor heave can be formed under the high stress function after the roadway construction. On this basis, the joint control measures (including concrete reserve arch and footing rockbolt) are proposed to be taken. In terms of the site inspection, it is indicated that the technology is capable of effectively controlling the mainroadway floor heave.

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Cushion Pad of Reducing Blasting Vibration - Starting New Era of Decreasing Disaster in Civil Engineering

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Millisecond delayed blasting has been widely used in reducing vibration of engineering blasting practice before. Pre-splitting blasting has been widely used in reducing vibration of rock slope excavation by blasting up to now. There was still damage to surrounding rock by millisecond delayed blasting and pre-split blasting even smooth blasting.

The recurrent blasting vibration will produce cumulative damage to surrounding rock mass of underground and rock slope engineering, even induce rock mass fracture, collapse, roof fall or instability landslide. The damage area is much larger than the blasting excavation area, so rock mass would be damaged several times and result in accumulative damage. Not only the disturbance of single blasting on the surrounding rock should be controlled during blasting construction of anchorage roadway or tunnel but the emphasis should be put on the accumulative vibration effect of surrounding rock induced by frequent short-distance blasting and the corresponding control measures should be taken.

The paper introduces a cushion pad which has simple structure and is easy used in blasting engineering. This device can not only avoid large amount of cracks on the rock slope and cumulative damage to surrounding rock mass upon blasting, but also cushion and hold up at large extent heavy detonation shock after blasting. It is first used in Panzhihua Xujiagou iron open pit, Huayinshan coal mine with gas in Si-Chuan province, Miaowei hydropower station in Yunnan province and Minshui tunnel blasting engineering in Xin-Fen highway in Hebei –Shanxi province. It effectively cushions the heavy detonation shock from explosion avoiding the damage surface of surrounding rock and accumulated damage of rock, thus improve stability of rock mass and save a large amount of support costs. The vibration velocity with cushion is 50% less than with pre-splitting blasting, even less than the threshold of blasting vibration accumulated damage. Ratio of semi--hole archive 95%. The study achieves China patents Nos. ZL201220107888.5, ZL 201220230579.7，ZL 201220750552.0., ZL 201220016697.8.

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Spatial-temporal Pattern of Socio-economic Vulnerability to Geohazards in Bailong River Basin, China

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Bailong River Basin, as an area with a high incidence of geohazards in China, has received increased concern from local governments and international academe (Meng et al. 2013). The socio-economic vulnerability (SEV) is the product of social and place inequalities (Cutter et. al, 2003) It describes the relationship between geohazards，ecosystem and social economy system so that it influences the ability of social-economic-ecological comprehensive systems （SEES)to prepare for, respond to, and recover from hazard events (Chen, et al., 2013). In our work, four hazard-related indicators were added to the previous evaluation indicator set of the SEV for reflecting the influence of geohazard characteristics on the SEES as geohazards bearing body in order to make up the defect ignored by previous studies. The analytic hierarchy process and fuzzy comprehensive evaluation method were applied to assess SEV index of 100 townships as analysis units in the basin during 2002-2011 comprehensively, which were divided into four levels. Meanwhile, spatial autocorrelation and hot spot analysis were used to evaluate and analyse the spatial-temporal pattern of the SEV index. The results showed that: 1) The highest SEV level towns were mainly found in Wudu District and its surrounding area, and the lowest SEV level towns mainly located in the northern basin including Diebu County, Tanchang County and northern Zhouqu County. 2) The SEV index in the basin tended to decrease over the decade. However, an increasing gathering trend of the highest SEV level towns was discovered mainly in Wudu District (Figure 1). The study can be an important reference for local government to make policies which should regard townships of Wudu District as key areas for hazard prevention and mitigation in the future.

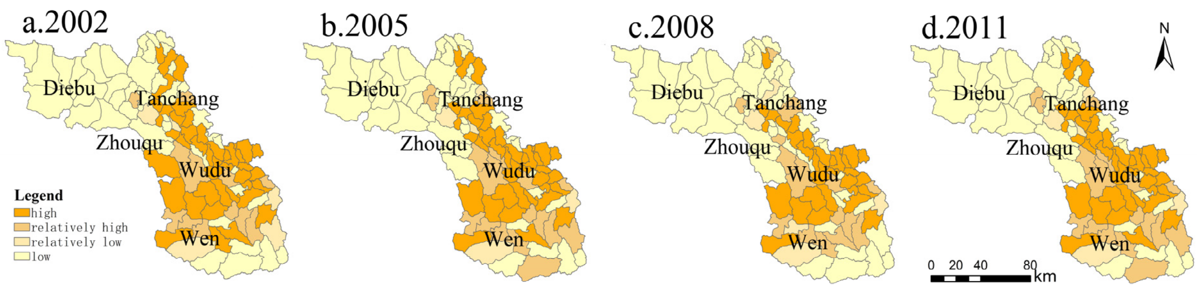

Figure 1. The Spatial Maps of the SV to Geohazards in Bailong River Basin.

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Experimental Study on Zonal Disintegration Phenomenon in Deep Rock Mass under Blasting Excavation

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To investigate the effect of blast loads on zonal disintegration phenomenon in deep rock mass, three dimensional geomechanical model experiment in high axial in-situ stress and blasting excavation is carried out by "capacity of deep rock breakage mechanics and supporting technique model test" in State Key Laboratory of Deep Coal Mining and Environment Protection. Model experiment results show that blast loads during blasting excavation will not only deteriorate the mechanical properties of surrounding rock, but also reduce its integrity. High axial in-situ stress intensifies the fracture level of surrounding rock and extends the fracture zone. After overload, the radial tensile strain of surrounding rock in all three positions, vault, side wall, and floor, presents a non-monotonic change, interval distribution of peaks and troughs, with distance to model roadway increasing, which indicates an obvious zonal disintegration phenomenon. After quantitative analysis of fracture zone distribution around model tunnel in blasting excavation, the radius of next fracture zone is about 1.28 times bigger than that of former fracture zone, seen in figure 1. Compared with model experiment results of anchorage deep tunnel, it is found that the combination of anchor bolt and anchor cable presents a good inhibition effect of zonal disintegration phenomenon. Meanwhile, anchorage deep tunnel in high axial in-situ stress and blasting excavation still has a tendency of zonal disintegration phenomenon in deep rock mass.

Figure 1. Macro fracture mode in deep rock mass under high axial in-situ stress and blast loads.

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Study on the Block-Water Capability of Main Roof Structures of Steep Coal Seams with Fully-Mechanized Caving

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During fully-mechanized caving in steep coal seams, the monitoring data of mine water inflow onsite show that when mining proceeds to a certain burial depth, the amount of water inflow from surface water and overlying aquifers induced significantly. The initial conclusion is that the main roof structure functions as a block-water layer. In this paper, based on the theory that the main roof of the steep long-wall work faces forms rock-steady structure in the direction of inclination and the assumption that the strata overlying the coal seam are permeable layers, a formula for calculating the burial depth necessary to ensure that the main roof structure is block-water is provided. In this paper, a mine is used as example in the calculations, and the similar material simulation experiment is performed to determine the values of the parameters in the formula.

The calculation shows that the burial depth at which the main roof structure of steep coal seam becomes block-water is 254.23 m, which is essentially in agreement with field monitoring data and the numerical simulation results by UDEC (Universal Distinct Element Code) progress. The analysis and the calculation show that the main roof structure has a certain level of impermeability.

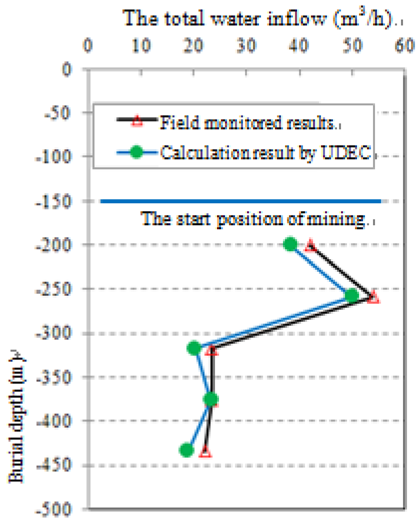

Figure 1. The relationship between total water inflow of the working faces and burial depth

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Vulnerability Assessment Model for Hazard Bearing Body Closed to Landslides Considering Run-out Process of Sliding Body

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Based on the situation that the assessment of vulnerability for hazard bearing body mainly depends on qualitative analysis at landslides risk assessment, a two-dimensional model using spring-deformable-block model is formulated to study the sliding process of landslides. On the assumption that motion form of landslides is continuous and variable, the sliding body is divided into lots of blocks. The change of width of block is chosen as the deformation of spring. Taking the accumulation and release of the deformation energy of block into account, the velocity, displacement and time of sliding body can be obtained based on kinematics analysis. From this data comes the impact force which is used as the strength of the landslide body. Then the hazard bearing body is analysed. When the inter-story displacement angle of weak story reached the limit value, the force worked on hazard bearing body is the resistance force. Dividing the strength of sliding body by the resistance of hazard bearing body gives the vulnerability value. Then the vulnerability of hazard bearing body being at different distance from the toe is discussed.

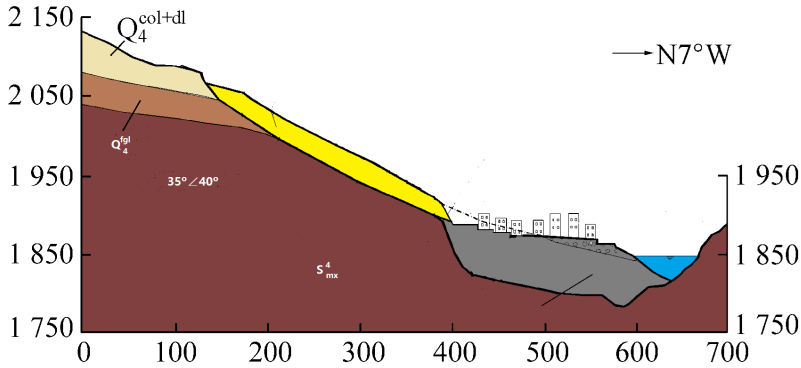

Figure 1. Cross-section of Danba landslide (Yin 2008).

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Synthetic Water Repellent Soils and Slope Engineering

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Water repellent soils, or hydrophobic soils, are described to have delayed wetting of soil surface and water infiltration. They have been studied by soil scientists and agriculturists for decades, and their potential applications in the field of slope engineering have been recognized recently.

Due to their ability to inhibit water infiltration while remaining gas permeable, water repellent soils are considered to be promising fill materials and impermeable barriers. Soil water repellency is widely observed to occur in nature because of organic matter, while in laboratory, it can be induced by coating the soil particles with a series of silane compounds. An advantage of synthetic water repellent soils is that the level of water repellency is adjustable, and therefore the rate of infiltration can be controlled in various scenarios (from no infiltration to fully wettable).

Since rainfall and subsequent infiltration are major contributors of fill slope failure, water repellent soils have been proved to be effective in hindering the generation of pore pressure and increasing the overall factor of safety during rainstorm. Landfill cover is another potential application for water repellent soils. Conventional cover systems like capillary barriers and evapotranspirative covers are proved to be effective in arid areas, while solutions for regions with heavy precipitation are still required. Comparing with its alternatives, water repellent soil is volumetrically stable and remains effective in the long term.

In this paper initial results and findings from a series of experimental flume tests are presented. The impacts of synthetic water repellent soils on slope engineering are considered.

Acknowledgements

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Effect of Micro-gas Inclusions on Abnormally Delayed Mechanical Behaviour of Intact Rocks after Excavation

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In-situ intact rocks can have an abnormally delayed behaviour that can occur after engineering excavation or tunnelling. Such behaviour normally and suddenly occurs in parts of the surrounding rocks at many minutes, hours, days, and months after the completion of excavation or tunnelling. Most importantly, intact rocks contain numerous small or tiny connected or isolated voids and pores with gas inclusions. Based on the fact of fluid (gas) inclusions, Yue (2012, 2014, 2015) proposed a hypothesis of originality that the abnormally delayed behaviour of intact rocks after excavation is caused by their micro-gas inclusions of high pressure.

In order to investigate and validate the hypothesis, a laboratory setup is developed to fabricate the rock-like solids with high pressure gas inclusions, as shown in Figure 1. Thus, the rock-like material can be lithified and formed at high compressive stress conditions. During the lithification process, the gas can be compressed and confined in the solid. Some initial results are presented here.

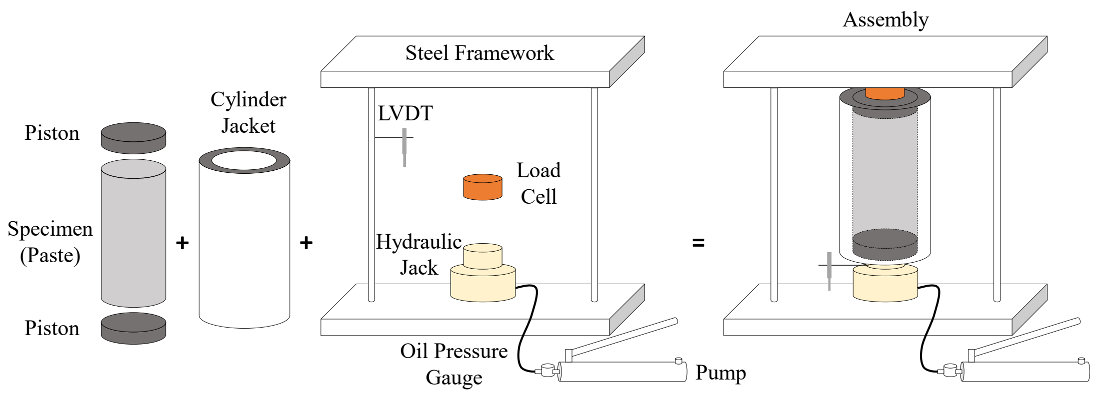

Figure 1. Schematic of experimental setup for rock-like material fabrication.

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Experimental and Numerical Study of Depositional Mechanism of Mudflows

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Mudflows tend to deposit after a rapid evolution on the steep channel down hillside. The large runout distance and deposit area are crucial concerns of geotechnical and geological engineers. In the rheological point of view, mudflows are non-Newtonian viscoplastic fluids which behave like a solid until submitted to a higher stress than the yield strength. Upon yielding, flow takes place and the flow behavior is described by viscosity. How viscosity and yield stress control the deposition of mudflows remains yet unclear due to the difficulties of performing large-scale experiments and scaling over a wide range of length scales.

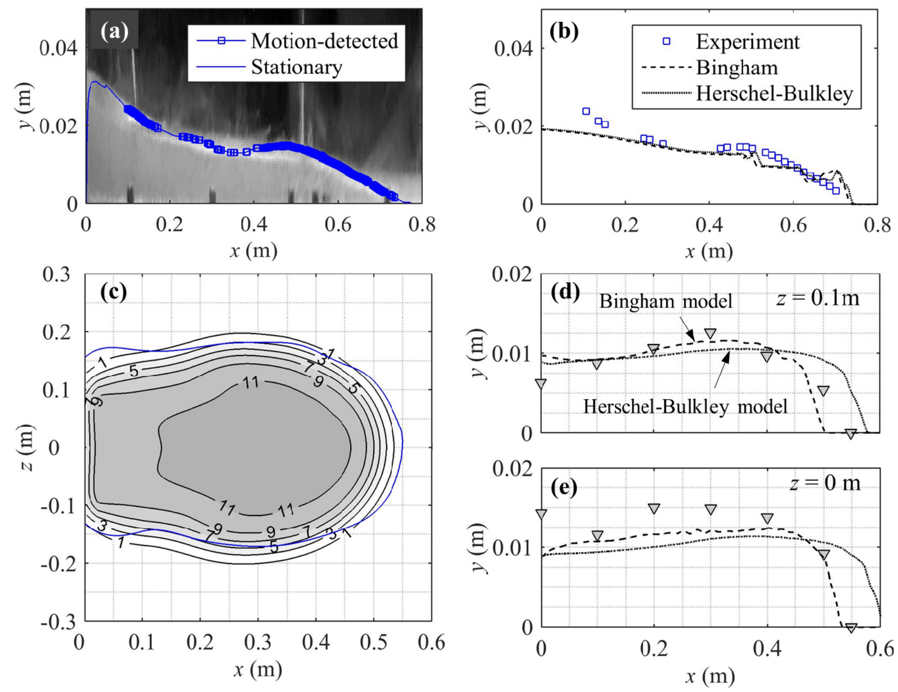

Figure 1. Flume test with water–kaolin slurry. (a–b) side views down channel; (c–e) final deposition at runout.

In this work, scaling of rheological parameters are proposed in a dimensional analysis. It is successfully used in numerical simulations to bridge the depositional behaviors of mudflows at different scales. The numerical modeling with Bingham and Herschel-Bulkley models are validated against small-scale flume experiments (Figure 1). The depositional mechanism of mudflows is associated with yield stress and viscosity. It is found that a deposition of slurry relevant to natural mudflows has the following features: (i) fast runout and stoppage due to relatively low viscosity; (ii) elongated shape due to fast runout (more stream-wise spreading than lateral spreading); (iii) remains stuck on the channel and steep edges due to high yield stress; (iv) flat deposit surface due to the effect of yield stress.

Shakedown Analysis of Lined Rock Cavern for Compressed Air Energy Storage

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Compressed air energy storage (CAES) systems have been used for the storage of very large amount of energy (Perazzelli and Anagnostou, 2015). The pressure of gas typically ranges between 10 to 30 MPa, and the operation of CAES system requires repeated compression and decompression cycles. The inner pressure is mainly resisted by the surrounding rock mass, while a layer of liner is usually installed for sealing; and this cavity is typically referred to as the lined rock cavern (LRC), as shown in Figure 1. Regarding to the rock deformation and the air leakage, the stability of LRC is then important for the underground storage of compressed air.

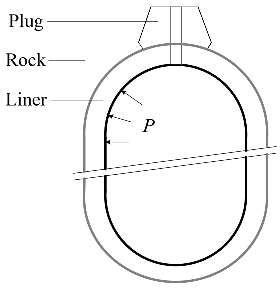

Figure 1. Schematic of a lined rock cavern.

Cavity expansion and contraction to avoid reverse yielding is of practical importance in geotechnical stability analysis (Yu, 2000); while shakedown analysis is concerned with the long-term capacity of an elastic-plastic structure subjected to cyclic loads (Wang and Yu, 2014). Analytical shakedown conditions for both cylindrical and spherical cavities in two layers of cohesive-frictional materials have been developed in this study. Shakedown limits are investigated in relation to the dimensions of a two-layered cavity system and the elastic/plastic material parameters. It is found that when the maximum cavity pressure is no higher than the shakedown limit of the layered system, reverse yielding does not occur even under the case of fully unloading. The shakedown analysis of two-layered cavities is thus applied to investigate the stability of lined rock cavern for compressed energy storage.

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Dynamic Loading of Carrara Marble in a Heated State

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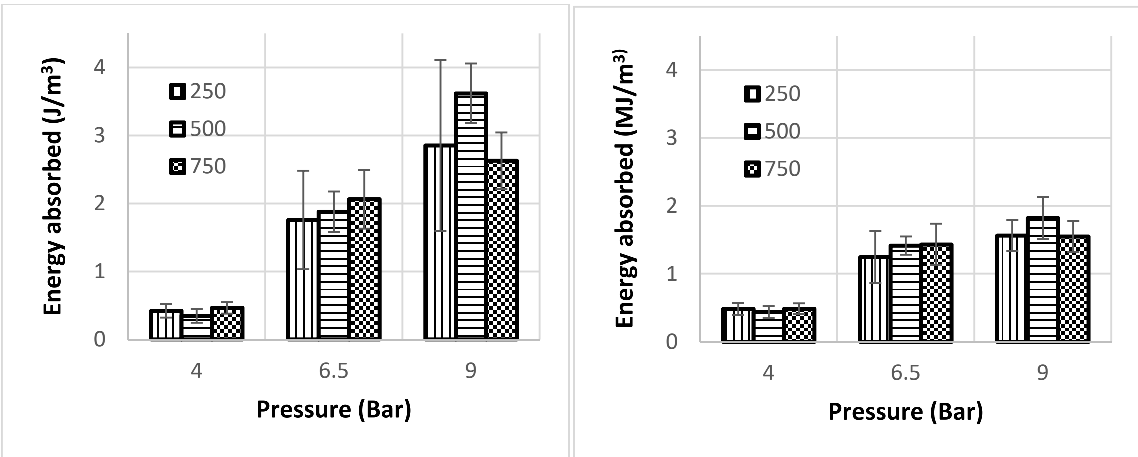
Fire and impact loading both have significant effects on the integrity of rock, and hence, rock caverns. However, present rock cavern design methods do not cater for these events. This study aims to provide a better understanding of the dynamic load capacity of Carrara marble at elevated temperatures. Dynamic uniaxial compression tests are performed on Carrara marble held at various temperatures using a Split Hopkinson Pressure Bar (SHPB) setup with varying input force. A customized oven is included in the SHPB setup to allow for the testing of marble specimens in a heated state. Although specimens heated at higher temperatures have lower dynamic compressive strength, figure 1 show that a similar amount of energy was dissipated for all specimens tested at the same pressure, regardless of the heating temperature. Our study revealed that factors including the failure type, fragment size distribution and strain history experienced by the marble specimens are significant in quantifying damage caused by dynamic loading to heated rocks.



(a) (b)

Fig. 1 Graphs of (a) total energy absorption, (b) energy absorption at peak stress; error bars represents ± 1 standard deviation

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Inverse Reliability Based Analysis and Design in Slope Engineering

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The presence of uncertainties in geotechnical engineering has always been recognized in the analysis and design of slopes. Geological anomalies, rock and soil properties, environmental conditions, and analytical models are all factors contributing to uncertainty. Conventional methods simplified the problem by considering the uncertain parameters to be deterministic, and accounted for the uncertainties through the use of empirical factors of safety.

This paper proposed a new inverse reliability based method for slope analysis and design, which considers the uncertainties in rocks and soils in a probabilistic frame. The aim of the new method is to find either single or multiple design variables in slope engineering corresponding to the specified reliability levels expressed by reliability index or by theoretical failure probability. In the present method, the Bishop simplified method is used to set up the performance functions of the slope design examples, and the first order reliability method is used to calculate the reliability index. Then a constrained optimization problem was formulated and solved by Newton-Raphson iterative algorithm, which can be easily programmed in MATLAB. The design parameters can be treated as a deterministic or as a random variable, such as slope angle, mean and standard deviation of soil properties.

This paper presents three examples to illustrate the validity and efficiency of the proposed inverse reliability based method in slope engineering. The first example is a fictitious inverse reliability problem, with a single design variable and specified reliability index 2.0. The second example is a design problem of a homogeneous slope, with three design variables and specified reliability index 3.16. The third example is about the backfill slope on a strip-mined bench to restore the terrain to the original contour, with three design variables and specified reliability index 2.46. The three design variables are the soil cohesion mean, the soil friction angle mean, and the slope angle. Results show that the proposed method can be used in slope design in geotechnical engineering practice and can be readily programmed in a software.

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Finite Element Solution of Elastoplastic Consolidation in Strain-softening Porous Media

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The 1D linear and elastic consolidation theory developed by Terzaghi is commonly used for evaluation of consolidation of geo-materials. Since most geo-materials are not strictly elastic and exhibit elastoplastic characteristics, elastoplastic consolidation analysis is necessary. Strain-softening phenomenon is very common in Petroleum Geomechanics, it is referred to as a behaviour where the stress reduces with continuous development of plastic strain. Fig1 shows the stress-strain relationship of marbles in laboratory triaxial compression experiment conducted by Wawersik and Fairhurst, obviously when confined pressure is in a certain level, it can be recognized as strain-softening model. In reservoir simulation, as the oil being pumped the stratum will subside, once geo-materials exhibit strain-softening, the subsidence will be notably compared to strain-hardening materials, thus it's important to analyze the consolidation process involving strain-softening geo-materials. However, the existing literature seldom addresses this kind of consolidation. The finite element method is incorporated to solve the fully coupled consolidation problem, and the Gurtin's variational principle introduced by Sandhu and Wilson is adopted to form the finite element formation.

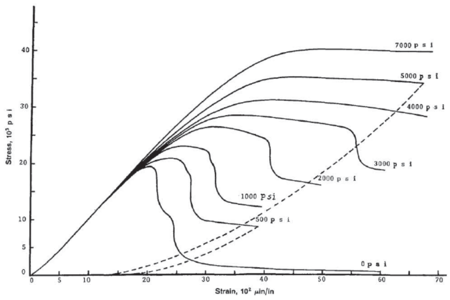

Figure 1. Complete stress-strain curves for unconfined and confined Tennessee marble.

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Geomechanics Parameter Characterization Using Numerical Modeling and Hydraulic Fracturing Test

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In deep naturally fractured oil and gas reservoirs, there is currently a challenge as far as natural fracture parameters. The goal of this study is to present characterization of petroelum geomechanics parameters by combining numerical modeling of hydraulic fracturing with intelligent identification methods. To perform hydraulic fracture treatment design and well trajectory optimization in petroleum engineering, the petroleum geomechanics parameters are usually known. Hydraulic fracturing (HF) tests and some laboratory measuremnts are generally carried out to obtain them. Thereinto, hydraulic fracturing test in new wells is used to obtain in–situ stresses. The largest and smallest principal in–situ stresses can be calculated by shut–in/closure pressure and breakdown/reopening pressure of HF. However, in–situ stresses obtained from HF in the traditional theoretical framework are not completely correct because the traditional method cannot solve the problem of error between the real minimum principal in-situ stress and shut-in/closure pressure of hydraulic fracturing. In addition, the traditional method cannot be used to calculate other parameters beyond in–situ stresses simultaneously, such as fracture spacing, fracture nomal stiffness and shear stiffness. Given these challenges, a hybrid artificial neural network (ANN) and genetic algorithm (GA) method is developed for identification of the principal in–situ stresses and natural fracture parameters. First, numerical modeling of hydraulic fracturing is performed to generate intelligence learning samples of ANN. Also, ANN model is applied to map the nonlinear relationship between geomechanics parameters and pressures of hydraulic fracturing test. Finally, GA is used to identify geomechanics properties on the basis of the fitness function established using pressures of hydraulic fracturing test. Results illustrate that inverse analysis model of pressure established by artificial neural network and genetic algorithm is able to provide a powerful and effective tool for multi–parameter identification, and it is also a cost– and time–saving method.

Deformation Response of Oil Reservoir Induced by Water Injection

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To improve the enhanced oil recovery (EOR) and keep a higher pressure of reservoir, water injection method was adapted in operation of oil field. However, water injection can upset the balance of reservoir pressure, which could lead to redistribution of stress and deformation and break of rocks. Based on the coupling theory of mechanics and hydraulics, a quarter reservoir model of five spot water flooding was established, and a numerical method was used to analyse the overall effect of water injection. The responses of stress and stain with the variation of different parameters were obtained. In this paper, three parameters were considered, namely, depth of reservoir, injection-withdrawal ratio (IWR) and elastic modules.

1. Water injection leads to redistribution of stress. After a period of injection, the reservoir pressure around injector is higher than producer, while the effective stress around injector is lower than producer. And bigger strain and deformation are observed around two wells. Simultaneously, the strain and deformation in the segment between two wells are lower than the surrounding of two wells.

2. The influence range of reservoir pressure around the injector is in a pear-shaped region which is bigger on the top and smaller on the bottom. A similar but slightly different condition is observed around producer where effective range is smaller on the top and bigger on the bottom, in an inverted-pear-shaped region.

3. With the increase of stratum depth, stress and reservoir pressure increases gradually. The normal strain and vertical subsidence reach maximum value at the top of reservoir and decrease with stratum depth increasing. The shear strain of top and bottom in reservoir is bigger than inner of reservoir, and the biggest appears on the top of the reservoir model.

4. Different IWRs have a significant effect on reservoir pressure. When IWR>1(=1.5:1), the pressure increases and the effective stress decreases. Otherwise, when IWR<1, the pressure is less and the effective stress is greater. The value of normal strain when IWR≠1 is bigger than balance injection performance（IWR=1）. Besides, the shear strain increases with IWR>1 and is in a low and balance value with IWR≤1.

5. Elastic modules mainly effects the strain and deformation of rocks. And strain and deformation are negatively related to the elastic modulus.

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Shearing Rate Effect on Residual Strength of Slip Soils and Its Impact on the Deformation Characteristics of Landslides

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The shearing rate in the sliding zone is expected to be very low, whilst during dynamic events such as rainfall or earthquakes the shearing rate can be orders of magnitude higher than during general conditions. The response of residual strength of slip soils varies significantly with the corresponding shearing rate. Thus, there is a need for an improved understanding of shearing rate effect on residual strength of slip soils in order to improve the level of stability analysis and design of countermeasures against the reactivation of landslides.

The Huanglianshu reactivated landslide in Three Gorges Reservoir area was triggered by the fluctuation of reservoir water level. The slip soils were taken from the back edge of the landslide. Using ring-shear testing on reconstituted soil samples over a wide shearing rate varied in a range of 0.2mm/min-20mm/min, this paper examines the impact of shearing rates on the residual strength of slip soils. The influences of moisture content and normal stress on shearing rate effect are discussed respectively. The result reveals that (1) The residual strength of slip soils increases linearly with an increase in the logarithm of shearing rates. Further, the equation which quantitatively assesses three types of shearing rate effect is presented: $\tau_r=\alpha\ln(\nu)+\beta$, where α is the rate effect coefficient. The residual strength of slip soils displays different effects of shearing rate, accompanying α. (2) α reaches the minimum value with the maximum moisture content and the minimum normal stress in the positive rate effect. (3) The deformation process of the Huanglianshu landslide is clarified by FLAC^{3D}. Due to the positive rate effect, the residual strength of slip soils has a noticeable fluctuation and the activated landslide gradually tends to become stable. The simulated result agrees well with the monitoring information approximately and may provide an explanation for the continuous accelerating–decelerating process of the landsliding.

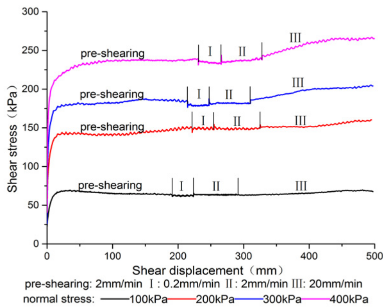

Figure 1. Typical results of various shearing rates.

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Completely Weathered Sandstone Slope Failure During Highway Construction and Its Remedy

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With the continuous development of China's economy, highway construction is increasing. The geological condition in the mountainous area of Western China is very complex, and the problem of slope instability is commonly encountered in highway construction. In practice, slope excavation is usually applied to reduce the inclination of slope and then reinforcement measures are applied to slope. But with the development of the slope deformation, the shear strength of rock or soil is weakened gradually, which is more significant in soft rock and loose deposit slope. The rock or soil shear strength deterioration, the enlargement of sliding range, the increase of reinforcement, the increase of project budget and the destruction of environment are often caused by the commonly procedure used in slope practice “excavation first, then reinforcements”. In the paper an active reinforcement method (Yuan et al, 2008) – “reinforcement first, then excavation”- is recommended for highway soft rock and loose deposit slope practice, which can make full use of inherent rock or soil strength, strengthen its bearing capacity, increase the slope stability and finally reduce the influence on highway construction and reduce the destruction of environment. The completely weathered sandstone slope failure in Xiao-Mo highway, Yunnan province is presented in the paper (Figure 1). Rock mass shear strength is analyzed for different slope construction and failure stages through back analysis method (Chen, 2003; Duncan and Wright, 2005) and the deterioration process of rock mass shear strength is obtained. According to the current rock mass shear strength and possible weakening shear strength of rock mass, the remedial measures for the failed slope is suggested. The results show that the amount of reinforcement works is greatly reduced, the budget of slope engineering is decreased and destruction of environment is avoided if the active reinforcement method is adopted to reinforce the slope before slope excavation.

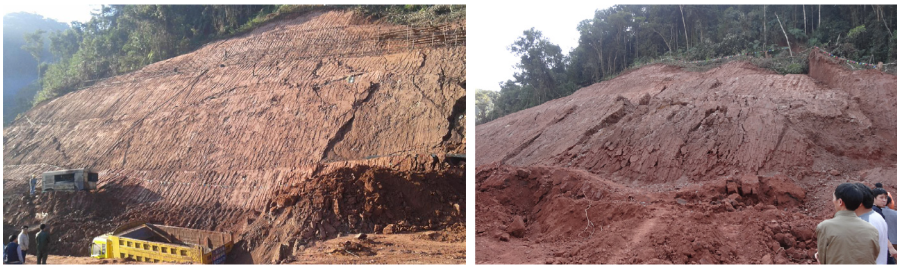

Figure 1 Fully-highly weathered sandstone slope failure in Xiao-Mo highway

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Mitigation Measures after "8.8" Zhouqu Debris Flow Disaster in Sanyanyu Valley, China

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A devastating debris flow occurred in the town of Zhouqu in Gansu Province, China, on 8th of August 2010, killing 1756 people and destroying the main urban area of Zhouqu. The Sanyanyu Valley, which contained nine check dams (all destroyed on 8th August) played a major role in the event. Following the "8.8" Zhouqu debris flow, the provincial government built 15 check dams as part of their hazard management project. This paper introduces the present management project in Sanyanyu Valley, simulates the effectiveness of check dams and discusses the long-term benefits of building check dams. The results indicate that the check dams are effective for controlling the small debris flows but not effective for the large-scale debris flows, and even cause negative impact for the both catchments. Check dams cannot effectively reduce the volume of loose source materials; rather, the construction process of check dams in the upper and middle reaches of debris flow gully induced slope failures on both sides of the valley (Figure 1). In the long term, ecological restoration, combined with check dams built in the downstream channel and deposition works on the debris fan, can decrease debris flow damage to an acceptable level to ensure the safety of Zhouqu County.

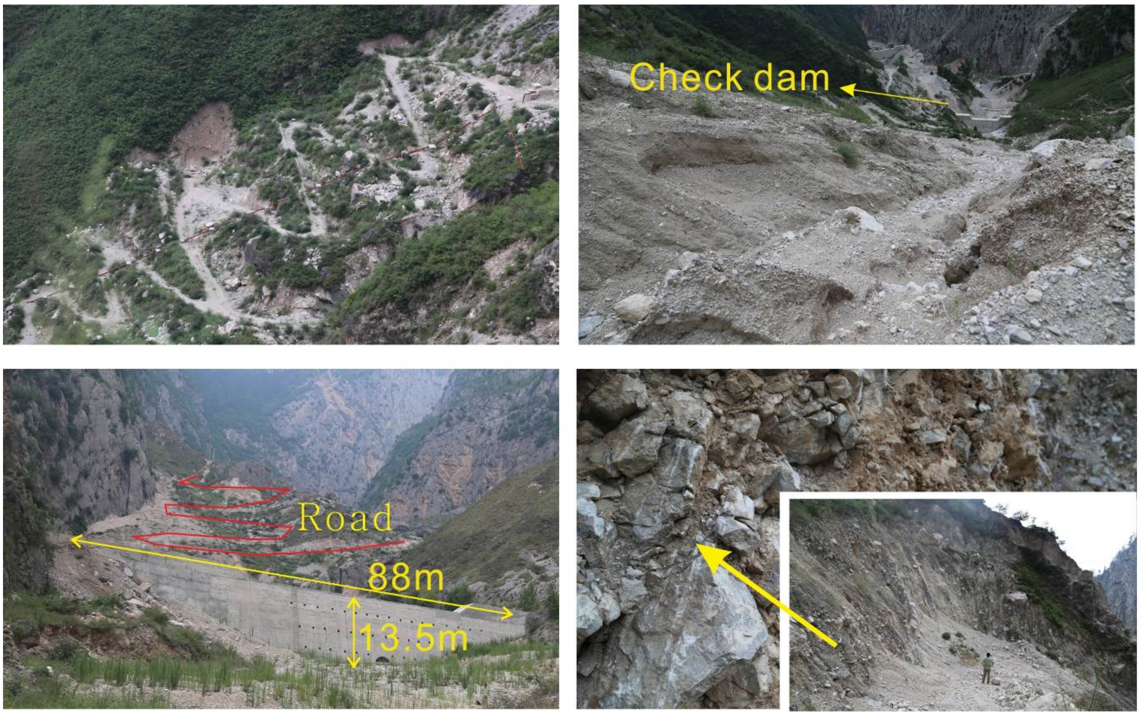

Figure 1. Slope failures caused by road building.

Response of Loess Landslide to Rainfall: Observation from Field Artificial Rainfall Experiment

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To investigate the response of a loess landslide to rainfall, a series of artificial rainfall experiments were conducted on a natural loess slope, located in the Bailong River Basin, Southern Gansu, China. The slope was instrumented in order to measure surface runoff, pore water pressure, soil water content, earth pressure, displacement and rainfall. The results indicate that most of the rainfall infiltrated into the loess landslide, and the pore water pressure, water content, earth pressure and displacement exhibited a rapid response to simulated rainfall events, which suggests that rainfall infiltration on the loess landslide was dominated mainly by the preferential flow through fissures and macropores. We observed three stages of change in pore water pressure, soil water content, earth pressure and deformation response of the loess landslide during the artificial rainfall events. Similar trends of infiltration variation were observed at the middle and toe of the slope; however, a quite different pattern was observed at the crest, which was determined by the antecedent soil moisture conditions, and the balance between water recharge and drainage in the corresponding section. Pore water pressure and deformation exhibited a complex pattern of interaction within the loess landslide. Slope movement was accelerated by the increased pore water pressure due to rainfall infiltration. A negative pore pressure feedback process was seen to occur in response to shear-induced dilation of soil material as the slope movement accelerated. The process of shear dilatant strengthening may explain why semi-continuous slope movement, caused by intermittent or continuous rainfall over long periods, can occur without triggering rapid slope failure.

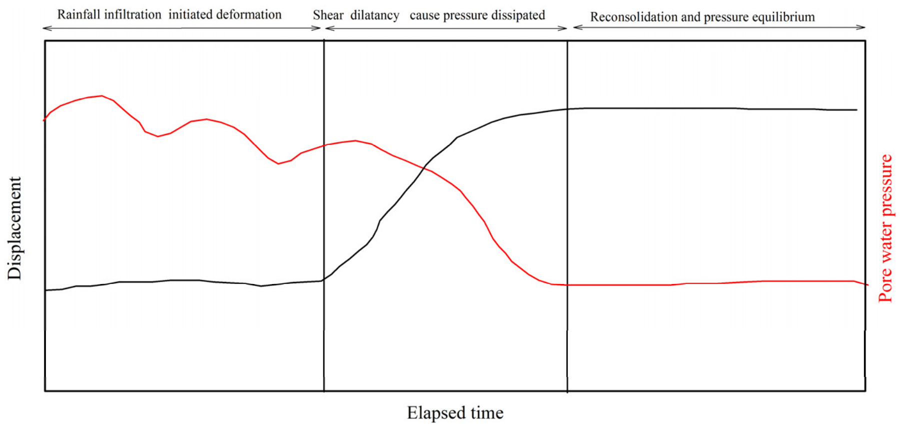

Figure 1. Conceptual graph of failure mechanism of the experiment loess slope.

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Integrated Physical-based Method for Analysis of Regional Heterogeneous Terrace Slope Stability

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Influenced by the uplift of the Qinghai-Tibetan Plateau and the down-cut of rivers, a series of fluvial terraces were formed in the western part of the loess plateau along the Yelleow River and its branches in China. Under the influence of increasingly fierce human activities, the slopes are more prone to generate landslides. Few of existing methods of evaluating regional stability have been applied to high heterogeneity terrace slope areas under different triggering conditions. Our study made a comprehensive analysis of the impact of natural factors and human activities on the stabilities of terrace slopes with the aid of three-dimensional laser terrain scanner, three-dimensional images of the subsurface, geological survey and laboratory soil mechanic tests. The shear resistance parameters of loess and silty clay formed in different historical stages with different water contents were obtained. Furthermore, three Limit Equilibrium methods were used in the distributed GIS to calculate the 16 different typical slope stabilities under 8 different water contents, 10 different slopes and under 0.2g earthquake loading in the study area. The results were validated by PS-InSAR and showed that Morgenstern-Price method achieved the highest accuracy rate of 75%.

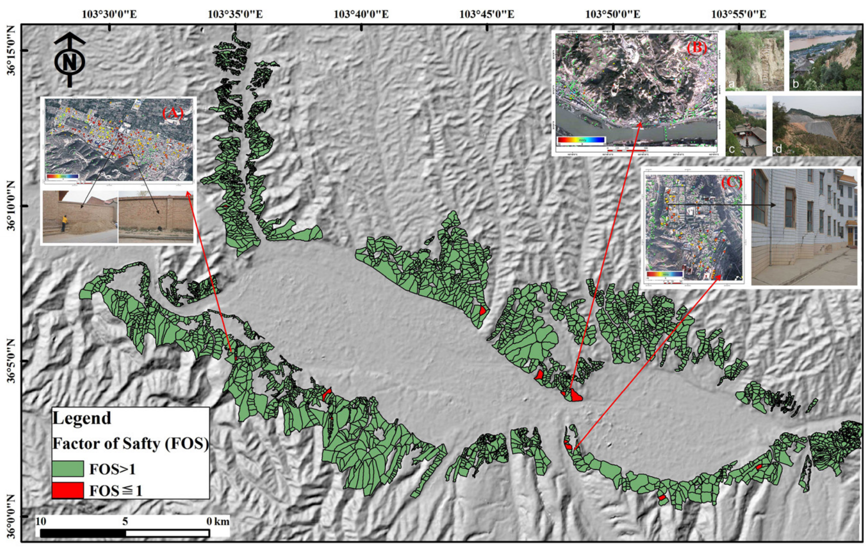

Figure 1. The validation of loess terrace slope stability results based on Morgenstern-Price method and PS-InSAR data.

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Analysis of Potential Surfaces of Multi-stage Slope Based on Local Strength Reduction Method

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Multi-stage slope commonly exists in the mountainous highway. The traditional global strength reduction method only finds the critical slip surface. However, the secondary slide surfaces are often ignored. To solve this problem, a new local strength reduction method (LSRM) is proposed and the process is shown as follows: a n-stage slope is assumed. Firstly, the n-stage slope can be divided into n+1 regions from top to bottom, and all the regions are discretized by finite elements and given the elastic material parameters. Secondly, for the region 1, the material parameters are replaced with the real material parameters and the traditional strength reduction method (SRM) is performed. Then, the plastic elements in the region 1 are replaced with the elastic material parameters, and the region 2 is given the real material parameters. Also the SRM is done on the modified region. Lastly, repeat these steps until region n+1 is analyzed. Consequently, the slip surfaces and safety factors are obtained, and the critical surface is easy to be found. In this study, the finite-elements strength reduction analysis is controlled by temperature fields. The feasibility of LSRM is verified by the multi-stage slope, shown in Figure 1. Some reasonable suggestions can be given by these potential surfaces for the slope reinforcement.

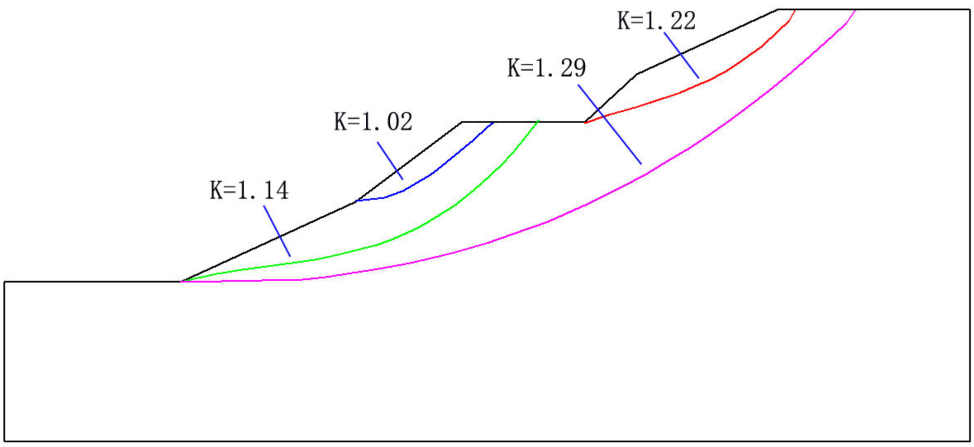

Figure 1. Critical failure surface and local minima from the LSRM.

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3D Hydraulic Fracturing Stress Measurement at Qirehataer Hydropower Project

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The Qirehataer hydropower project under construction is located in the Xinjiang Uygur Autonomous Region. Additional investigation is needed to be implemented in bad geological area at the location of downstream surge shaft. Therefore, the experimental determination of in-situ rock stress is required.

Based on the 3D stress measurement theory, the stress state calculation of one site needs the stress measurement results in 3 boreholes. Firstly, the stress measurement was conducted in each borehole by the hydraulic fracturing stress measurement system (HFSMS). At this course, the curves of the pressure against time were recorded by data collecting software. Secondly, according to the stress measurement results, the orientation tests were performed for three test intervals, where the intervals with obvious break pressure were chosen as far as possible. Finally, the 3D stress measurement results were obtained based on the measurement results in each borehole.

The 3D stress results in the following are obtained based on the 3D hydraulic fracturing stress measurements theory. For calculation, the rules for selecting the stress value in boreholes are as follows: If the stress value varied slightly along borehole depth, the average value will be picked up. If the measurement value has obvious deviation to the average, it will be discarded. The values are listed in Table1.

As Table 1 shows, the magnitude of major principal stress σ_1 is 29.83MPa, with its azimuth of 308° and dip angle of 56°, which indicates the orientation of major principal stress is approximately vertical. The magnitude of intermediate principal stress σ_2 is 22.28MPa, with an azimuth of 116° and dip angle of 34°, which indicates the orientation of intermediate principal stress is approximately horizontal. The magnitude of the minor principal stress σ_3 is 13.15MPa and its azimuth and dip angle are 210° and 6°, respectively, indicating a horizon pointing trend. The results indicate a vertical dominant stress mechanism.

Table 1. 3D stress measurement calculation results

Principal stress	Value(MPa)	Azimuth	Dip angle	Components of stress (MPa)	
σ_1	29.83	308°	56°	σ_X =16.4	τ_{XY} =5.07
σ_2	22.28	116°	34°	σ_Y =21.53	τ_{YZ} =-2.3
σ_3	13.15	210°	6°	σ_Z =27.33	τ_{XZ} =-2.97

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Search for Sliding Surface of Slope Based on Dynamic Strength Reduction Method

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Slope failure is a very common disaster in hilly regions, especially sliding disasters of heterogeneous rocky slope. The failure of slope is a progressive process where the whole sliding surface gradually evolves from the local damaged region in the slope. Based on the yield weakening of geotechnical material, a new sliding surface search method that can simulate the progressive failure of slope was proposed. The strength parameter of the damaged region was reduced, and then mechanical equilibrium of slope was calculated. Through the continuous local damage reduction of the strength parameters of the damaged slope body, the potential sliding surface damaged gradually and evolved to breakthrough finally (Fig.1).

The weak layer is closely associated with the stability of the heterogeneous rocky slope, but traditional calculation method is difficult to determine the failure mode. Present article mainly deals with the analysis of the stability of Dagangshan Mountain slope of Sichuan Province in China. The prevention flow of sliding disaster for heterogeneous rocky slope is presented. At first, Dynamic Strength Reduction Method (DSRM) was used to search the sliding surface, failure position and sliding direction. The case study of Dagangshan Mountain slope shows that DSRM is reasonable and correct when it is compared with the field observations. The study indicates that the sliding disaster of the slope is connected with f231 fault. The calculation results provide theoretical basis for the support and reinforcement program. In conclusion, DSRM provides a new calculation method for the stability and disaster forecast of similar heterogeneous rocky slopes.

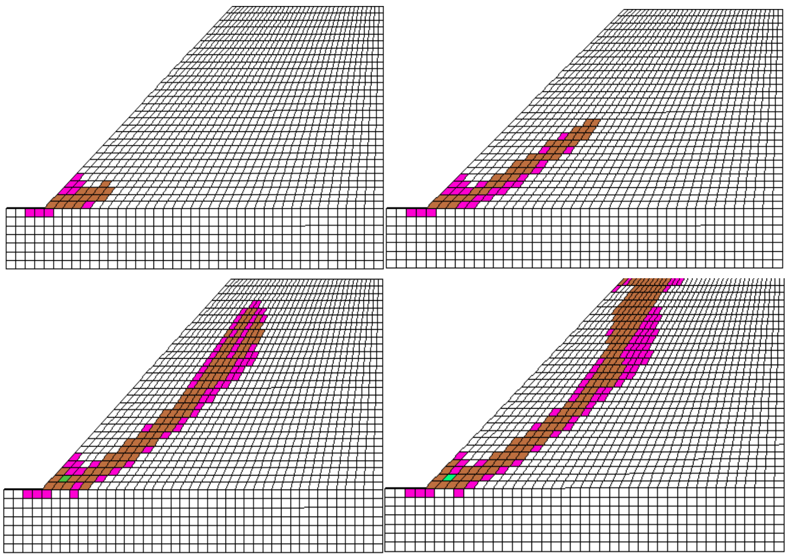

Fig.1 Evolution process of failure by the DSRM

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Impact Response Characteristics of Granite with a Tunnel-like Structure

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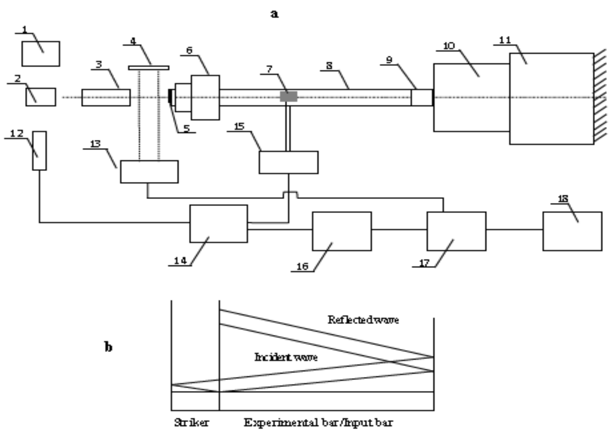
Caverns are a type of common structure in geology and rock engineering. In order to simulate the response characteristics of rock mass with open-hole structure under high speed impact loading, granite samples with tunnel-like structure are designed. A new dynamics simulation test system(as shown in Figure 1) is used to measure the stress wave in the experimental bar for the rock under progressive cycle impact load. The results show that the peak reflected stress ratio is independent of impact energy, however, the specific reflected strain energy decreases with the increase of impact energy. The cavern structure has little effect on the response of reflected stress wave under low impact energy. With the increase of impact energy, the effect of cavern structure to the response is intensified. The rock mass is split along the axis of the tunnel-like structure, the specific reflected strain energy increases significantly after rock failure. An abrupt leap of the specific reflected strain energy occurs when the cavern structure is nearly broken, which provides a theoretical basis for the advance identification of cavern structure such as karst caves while drilling.



1-pressure source; 2-pressure regulator; 3-pulse generator; 4, 13-line laser velocimetry sensor; 5-pulse shaper; 6-momentum trap; 7-strain transducer; 8-experimental rod; 9-diamond bit; 10-rock specimen; 11-rigid fixed end; 12-pressure transducers; 14-switching box; 15-interface; 16-digital dynamic strain gauge; 17- data integration box; 18-computer.

Figure 1. Schematics of impact response test simulation system.

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Mechanism and Theoretical Model of Intermediate Principal Stress Effect on Rock Strength

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Most of true triaxial tests on rock specimens show that with the increase of intermediate principal stress, rock strength has an initial increase and a subsequent decrease. However, the physical mechanism of such an effect is not clear. In this paper, numerical simulations of true triaxial tests are conducted by using PFC3D model. The simulation results show that the restraint and promotion of micro cracks in different directions lead to the intermediate principal stress effect. Then, a failure probability model is developed to describe the intermediate principal stress effect on rock strength. Each shear plane in rock specimens is considered as a micro-unit. The strengths of these micro-units are assumed to match Weibull distribution. The macro strength of rock sample is a synthetic consideration of all directions' probabilities. New model reproduces the typical phenomenon of intermediate principal stress effect that occurs in some true triaxial experiments, as shown in Figure 1(a). Based on the new model, a strength criterion is proposed and it can be regarded as a modified Mohr-Coulomb criterion with a uniformity coefficient. New strength criterion can quantitatively reflect the intermediate principal stress effect on rock strength and matches previously published experimental results better than common strength criteria, as shown in Figure 1(b).

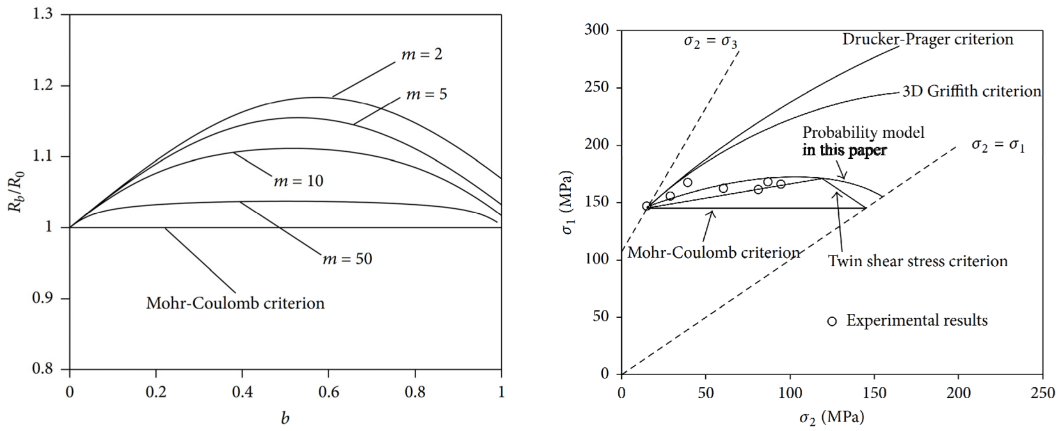

Figure 1. Rocks failure probability model: (a) with different uniformity coefficient; (b) in comparison with common strength criteria.

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Research of Surrounding Rock Failure Mechanism of Gripper During TBM Tunnelling

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Large formation or buckling failure of tunnel surrounding rock will easily occur for the TBM construction under weak and broken formation conditions. The problems such as the gripper failure or unstable supported gripper can cause problem to TBM. In this paper, this problem is investigated numerically. The main research contents are as follows: (1) Analysed and summarized the research achievements of TBM gripper and tunnel surrounding rock interaction of both domestic and overseas. On the whole, the research of TBM tunnelling gripper supporting force is currently deficient. The estimation of gripper supporting force is mainly based on the engineering experience or the empirical formula. Thus, more detailed research should be made, for the failure mode of tunnel surrounding rock during the TBM tunnelling process. (2) Used the continuum finite element software ABAQUS to comprehensively analyse the interaction between the TBM gripper and tunnel surrounding rock and the deformation and failure mode of surrounding rock, with the consideration of surrounding rock strength, surrounding rock grade, tunnel depth and tunnel diameter etc. (3) Analysed and compared the variation range and trend of unilateral TBM gripper supporting force under four surrounding rock conditions. Then, the interaction law between the TBM gripper supporting force and surrounding rock conditions will be summarized. The research results in this paper have important guiding significance for the calculation of TBM gripper bearing capacity and the field construction under complex geological conditions.

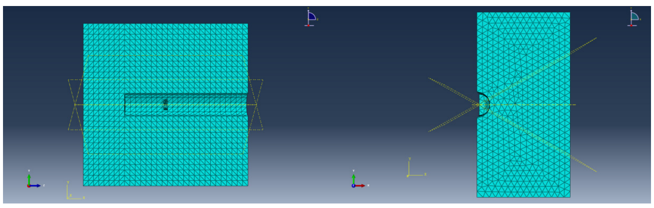

Figure 1. Mesh modelling of ABAQUS model.

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Slope Stability Analysis Considering Effect of Underground Mining

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The slope stability has a great influence on the safety of phosphate rock mining during the transition from open pit into underground mining. The deformation and stability of both open-pit mine slopes are analyzed and investigated with the usage of plane-strain similar model test and numerical simulation. Research results show that: Maximum displacement occurs in the middle of the roof and develops towards the mine goaf, and the displacement contour forms an irregular arch shape. Filling with high strength can prevent the surrounding rock from failing, and decrease the range of surface subsidence and the amount of subsidence. During the mining process using overhead cut and fill stopping method, the stability factor of the right slope will gradually decrease first, and will decrease rapidly while mining is near the foot of the slope. The model test results reveal that obvious shear failure occurs on the foot of the slope under overloading condition, which would cause slope failing.

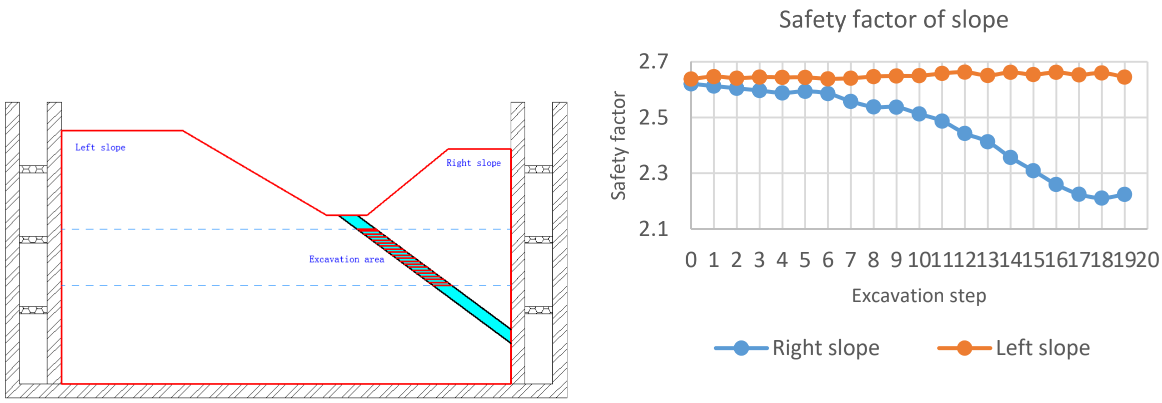

Figure 1. Safety factor of slope.

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Study on Stability of Deep Slope with Triplex-Row Piles Supporting

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When broadening and regulating canal which has large number of high-rise buildings nearby, it is necessary to control the deformation of slope supporting structure strictly and ensure the stability of slope to guarantee the safety of the construction and surrounding buildings. Based on the retreat construction of canal slope that is supported by triplex-row anti-slide piles, the evolution law of the canal slope stability, and the influence of the qualities of anti-slide pile and cement mixing piles on slope stability factor and sliding surface shape are analyzed and investigated. A modified triplex-row pile computational model is presented on the basis of the finite element and theoretical analyses of bearing capacity and deformation characteristics of the triplex-row pile supporting structures. Furthermore, an economic and reasonable triplex-row piles supporting proposal for the relying engineering is proposed, which can provide the beneficial reference to the design and construction of similar multi-row anti-slide piles.

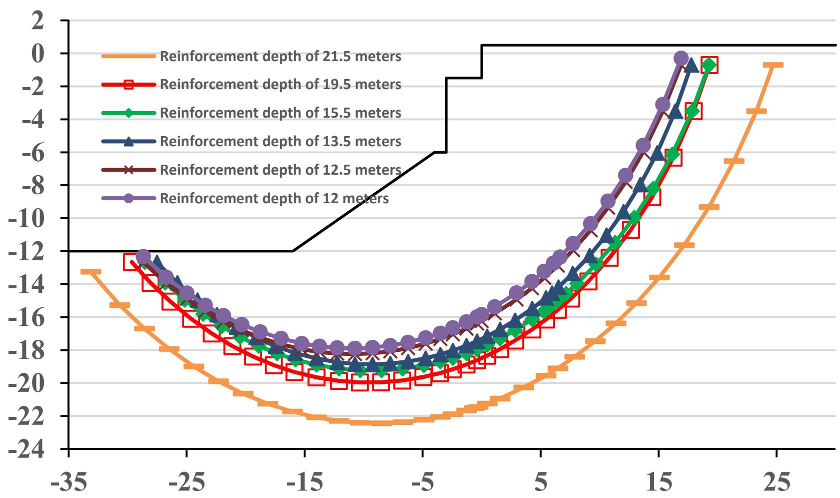

Figure 1. Slip plane with different reinforcement depth

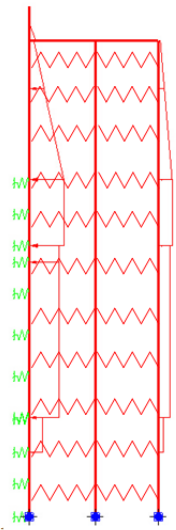

Figure 2. Calculation model of triplex-row piles

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Failure Mechanism and Stability Analysis of an Active Landslide in the Xiangjiaba Reservoir Area

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Dam construction for hydropower development is a very important subject matter all around the world, especially in developing countries due to energy crises. Filling of reservoir lakes may trigger or re-activate landslides in reservoir area. Active landslides in populated districts in the Xiangjiaba reservoir area have become a striking problem for residents, local government and construction engineers. The key objective of this study is to analyze the role of reservoir filling and fluctuation in the activation/reactivation of the landslide as well as the mechanism of landslide from microstructures of pre-sheared slip surface. A large active landslide with a total volume of 125×104m3 at the left margin of Jinsha River in Pingshan county of Sichuan Province, Southwest China, was selected as a case study. Field investigation, field monitoring and laboratory tests were carried out to find out the failure mechanism and the stability of the active landslide. The shear strength test and stability analysis confirm that the water level fluctuations have an adverse effect on slope stability. It is obvious from microstructure analysis that the clay minerals contribute to down-slope movement at micro-scale as well as presence of expansive minerals (e.g.; Montmorillonite) decreases the strength of soil due to water level rise.

Effect of Confining Pressure and Water Content on Compressive Strength and Deformation of Ice-rich Silty Sand

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A series of unconsolidated-undrained triaxial compression test was conducted to investigate the strength and deformation of ice-rich silty sand with different volumetric ice contents and confining pressures. The results show that the strain behavior of ice-rich silty sand had three components, including strong strain softening, strain hardening, and weak strain softening. These components occurred under different combinations of volumetric ice content and confining pressure. The strength and failure strain on ice-rich silty sand varied with confining pressure and volumetric ice content. As the volumetric ice content increased from saturation at the maximum dry density, the strength decreased to a minimum value, then increased to that of pure ice (Figure 1). Under these conditions, the failure strain increased to a maximum value, and then dropped with a slight increase in the volumetric ice content to a constant value equal to that of ice. A transition zone between about 50.2 and 61.9 % volumetric ice content was identified. This transition separates the sample behavior of frozen soil from ice. The strength remained nearly constant at various confining pressures for volumetric ice contents from about 50.2-75.0 %, and at other volumetric ice contents, the strength increased with increasing confining pressure.

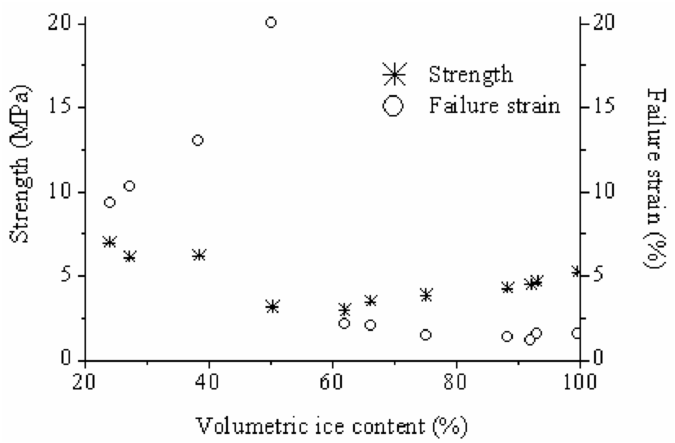

Figure 1. Comparison of strength with failure strain under a confining pressure of 0.05 MPa

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Stress and Deformation Characteristics of Transmission Tower Foundations on Permafrost

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A transmission tower foundation embedded in frozen soil is subject to both the wind-induced uplift and frost heave forces. To evaluate the engineering risk and ensure the safety of the Qinghai-Tibet Power Transmission Line (QTPTL) system, stress sensors were installed at the bases of two test tower foundations to investigate the stress state of the tower foundations (Figure 1). Using data on air and ground temperatures, and the deformation of tower foundations, we analysed the stress variation, and the causes were discussed here. The results showed that the stresses at the bases of tower foundations had a close relationship with air and ground temperatures. The cooling of the underlying soils led to the occurrence of frost heave, which pushed the foundations upward and caused a significant stress bulb under the bases of tower foundations. Seasonal variations in the contact stress depended on the seasonal freezing and thawing of foundation soil. The contact stress increased with the cooling of the underlying soils and decreased with the warming of the underlying soils. The results also showed that the contact stress was free of the wind influence, i.e., the wind-induced uplift force was minor for the contact stress. A thermal-elastic-plastic finite element simulation results showed that the frost heave force induced by soil freezing potentially threatens the safety and normal operation of the QTPTL. Thaw settlement may lead to harmful deformation of tower foundations if global warming is considered in the numerical model. The remedial measure with thermosyphons only can reduce the settlement of the foundation and will increase the frost jacking risk of the foundation.

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