



## International Society for Soil Mechanics and Geotechnical Engineering

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## Research highlights

### Hong Kong University of Science and Technology (HKUST) Geotechnical Group

#### 1. Introduction

The Hong Kong University of Science and Technology (HKUST) was established in 1991. The main campus is ideally located within the natural beauty of the Clear Water Bay peninsula in East Kowloon, Hong Kong (Fig. 1). The serenity of the setting creates the perfect environment for research. The HKUST has four major schools: Engineering, Science, Business and Management, and Humanities & Social Science. The total number of undergraduate students is about 9,500 and that of postgraduate students is about 4,300. The Department of Civil and Environmental Engineering is one of six engineering departments and the geotechnical group at HKUST is one of several research groups within the Department. The group comprises six professors and two research assistant professors.

HKUST 2005-2020 is a strategic plan set out by the university with becoming a world leader in environmental and sustainable development as one of its milestones. The geotechnical group's interests range from fundamental to applied research in broad areas: constitutive and numerical modelling of static and cyclic saturated and unsaturated soil behaviour at various temperatures; multi-phase flow in soil; mechanical behaviour of granular soil; physico-chemical soil behaviour of clayey soil; soil testing techniques; dynamic soil properties; wave-based characterization of geomaterials; development of innovative geomaterials; geo-energy issues including energy pile foundation and off-shore foundation engineering, geo-environmental problems such as innovative membrane-free landfill covers and green slope engineering; onshore soil-structure interaction involving piles, tunnels, and deep excavation; and the risk and reliability modelling of geotechnical performance.

## Research highlights

### Hong Kong University of Science and Technology (HKUST) Geotechnical Group (Con't)

The research is facilitated by the advanced HKUST geotechnical engineering laboratory as well as the state-of-the-art Geotechnical Centrifuge Facility (GCF) at HKUST, which is one-of-a-kind in Hong Kong.

This report first introduces the faculty members in the group and their respective research interests. The GCF and other state-of-the-art equipment used in their research are then presented. Some of their major research projects are then highlighted to showcase the holistic research approach the group encourages. Finally, social activities and recent conferences hosted by the group are described.

More information about the group can be found at: <http://www.ce.ust.hk/research/geotechnical.html>



Figure 1. HKUST campus

## Research highlights

### Hong Kong University of Science and Technology (HKUST) Geotechnical Group (Con't)

#### 2. Faculty

Prof. Charles W.W. Ng, Chair Professor

Website: <http://www.ce.ust.hk/faculty/cecwwng.asp>



Professor Charles W.W. Ng is an Associate Vice-President for Research and Graduate Studies and a Chair Professor in the Department of Civil and Environmental Engineering at the Hong Kong University of Science and Technology. He was an Overseas Fellow from the Churchill College, Cambridge University, in 2005 and Changjiang Chair Professor in Geotechnical Engineering in 2010. He is Fellow of the Institution of Civil Engineers (FICE), the American Society of Civil Engineers (FASCE), and the Hong Kong Academy of Engineering Sciences.

Professor Ng is the President of the Hong Kong Geotechnical Society. He served on the board of the International Society for Soil Mechanics and Geotechnical Engineering (ISSMGE) from 2010 to 2013. Currently he chairs the board-level Awards Committee and has been the Editor-in-Chief of the ISSMGE Bulletin since 2014. Professor Ng is an Associate Editor of the Canadian Geotechnical Journal and has served on many other editorial boards.

Professor Ng has been leading three large-scale inter-disciplinary research projects: (i) Understanding debris flow mechanisms and mitigating risks for a sustainable Hong Kong; (ii) Green slope engineering: bioengineered, live cover systems for man-made fill slopes and landfill capillary barriers in Hong Kong, and (iii) Green slope engineering. He organised the inaugural International Conference on Geo-Energy and Geo-Environment in 2015 (GeGe2015) at HKUST. The second “GeGe” conference will be held in 2017 at Zhejiang University, China and the third in 2019 at École Polytechnique Fédérale de Lausanne (EPFL), Switzerland. Selected papers are published in three refereed journals.

Professor Ng has solely supervised and graduated more than 30 PhD and 35 MPhil students. His current research students come from 16 different countries (see Fig. 2). He has published some 230 SCI articles in reputable international journals and delivered many keynotes, general reports and state-of-the-art reports in five continents. He is the main author of two reference books (i) Soil-structure Engineering of Deep Foundations, Excavations and Tunnels and (ii) Advanced Unsaturated Soil Mechanics and Engineering. He is also the lead editor of two major conference proceedings the 6<sup>th</sup> International Conference on Physical Modelling in Geotechnics in 2006 and the 6<sup>th</sup> International Symposium on Geotechnical Aspects of Underground Construction in Soft Ground in 2009 (see Fig. 3). In recent years he has placed a stronger focus on geo-energy and geo-environmental research to address sustainability concerns in the field of geotechnics. His current research areas include bioengineered slopes and live cover systems; fundamental investigations into sustainable and preventive measures for municipal solid waste landfills; sustainable mitigation measures against debris flows; energy pile studies; climate change impact on unsaturated soil; fundamental investigations on lateritic soil behaviour; and off-shore studies including methane hydrate-bearing sediments, pipelines and foundations for energy structures (i.e. wind turbine foundations).



Figure 2. Prof. Ng's current research students and post-docs (with 16 different nationalities)



Figure 3. Two reference books and three volumes of the two conference proceedings that Prof. Ng edited

## Research highlights

### Hong Kong University of Science and Technology (HKUST) Geotechnical Group (Con't)

Prof. Limin Zhang, Professor

Website: <http://ihome.ust.hk/~cezhang/>



Limin Zhang is Professor of Geotechnical Engineering and Director of Geotechnical Centrifuge Facility at the Hong Kong University of Science and Technology, and Changjiang Scholars Chair Professor of Ministry of Education, China. He is a Fellow of the American Society of Civil Engineers, Immediate Past Chair of Geotechnical Safety Network (GEOSNet), Vice Chair of the International Press-In Association, Past President of the ASCE Hong Kong Section, Editor-in-Chief of International Journal Georisk, Associate Editor of ASCE's Journal of Geotechnical and Geoenvironmental Engineering, and editorial board member of several other journals. Prof Zhang's research areas include slopes and embankment dams, geotechnical risk assessment, reliability-based design, pile foundations, and centrifuge modelling. He has led a project on landslide risk assessment and risk-based design for the reconstruction of a major highway near the epicenter of the Wenchuan earthquake, and is leading a collaborative research project on coping with landslide risks in Hong Kong under extreme storms. He has published over 200 international journal papers, delivered over 50 keynote or invited lectures, and received numerous research awards.

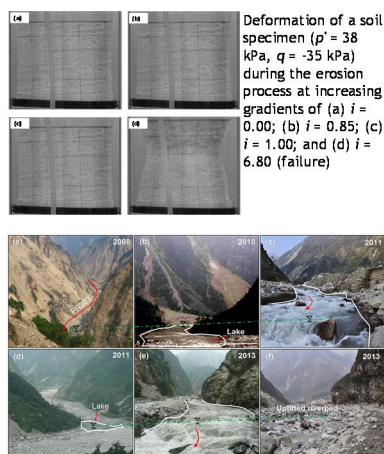


Figure 4. Evolution of landslide hazards over time near the epicentre of the Wenchuan earthquake

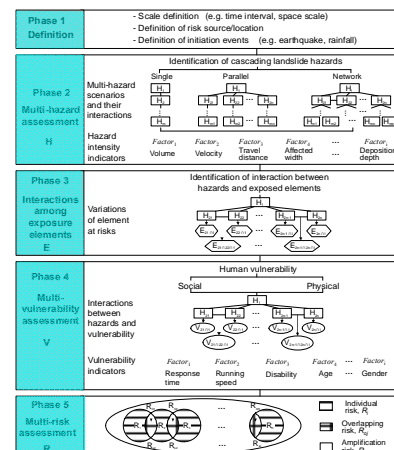


Figure 5. HKUST multi-hazard risk assessment procedure

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- Zhang, S. & Zhang, L.M. (2017). Impact of the 2008 Wenchuan earthquake in China on subsequent long-term debris flow activities in the epicentral area. *Geomorphology* **276**, 86-103.



## Research highlights

### Hong Kong University of Science and Technology (HKUST) Geotechnical Group (Con't)

Prof. Yu-Hsing Wang, Professor

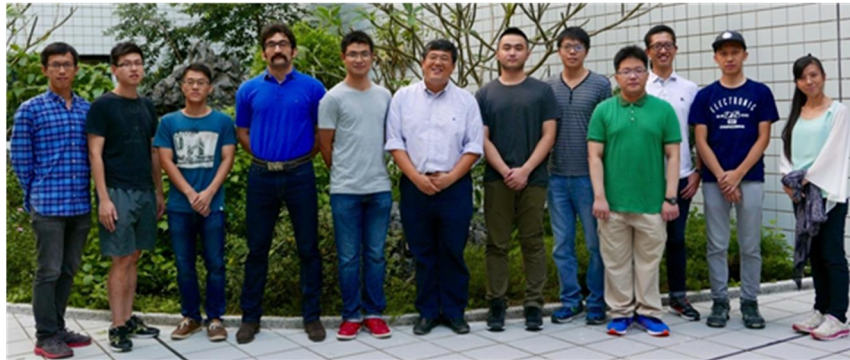


Figure 6. Prof. Y.H. Wang and his research group

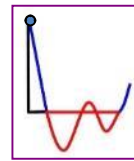
Website: <http://ihome.ust.hk/~ceyhwang/>

Founder and Director of Geomaker space:

- Lab of Wave-Based Characterizations
- Data Enables Scalable Research Laboratory (DESR)

Founder and Director of Digital Labs/platforms:

- Intelligent Dynamic Slope Information System, *iDynaSIS*
- GeoMaker: A Community-driven Innovation Platform for 3D Printed Customizable Geotechnical Testing



**DESRlab**

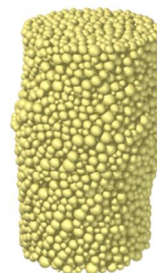
Prof. Yu-Hsing Wang received his B.S. and M.S. degrees from National Taiwan University and a Ph.D. from Georgia Institute of Technology where he obtained the George F. Sowers Distinguished Graduate Student Award. His research interests include innovative wave-based characterizations of geomaterials (using mechanical and electromagnetic waves), experimental Geo-micromechanics and DEM simulations, development of Open Smart Soil Particles (OpenSSP sensors), applications of geotechnical internet of things (GeoloT), Big Data Analytics, and Deep Learning on geotechnical engineering monitoring, applications of 3D printing techniques on innovation of geotechnical testing device and sensing techniques; physico-chemical clay behaviour, initiation mechanisms of flow landslides, and attenuation mechanisms and measurements in particulate media. He received the ASTM International Hogentogler Award in 2005, the School of Engineering Teaching Award, HKUST, in 2008, and the Distinguished Alumni Award from the Department of Civil Engineering, NTU, in 2013. He has been invited for Keynote and theme lectures in the international conferences and served as an associated editor and editorial board member in different journals.



3D printed Geotechnical Testing Device



Geo-IoT sensor node



DEM simulations



Wave-based characterizations

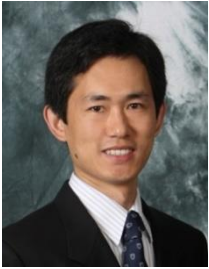
Figure 7. Prof. Y.H. Wang's research interests

## Research highlights

### Hong Kong University of Science and Technology (HKUST) Geotechnical Group (Con't)

Prof. Jidong Zhao, Associate Professor

Website: <http://ihome.ust.hk/~jzhao/>



Jidong Zhao is Associate Professor of Geomechanics at HKUST. His research is focused on developing innovative multiscale and multiphysics computational tools to advance fundamental understanding of the mechanics and physics of granular media in an engineering context. His contributions include: (1) DEM identification of unique anisotropic critical state (Fig. 8, Zhao and Guo 2013); (2) fabric-based anisotropic failure criteria and constitutive soil models (Gao *et al.* 2010, 2014); (3) hierarchical multiscale modelling of saturated granular media based on FEM-DEM coupling (Fig. 9, Guo and Zhao 2014, 2016); (4) discrete-based modelling of fluid-particle interactions (Zhao and Shan 2013) and (5) particle morphology characterization and modelling based on Fourier-shape descriptors (Fig. 10, Mollon and Zhao 2014). His research findings have been applied to engineering problems such as shear bands, soil liquefaction, debris flow mitigated by flexible barrier (Fig. 11) and borehole stability in petroleum geomechanics.

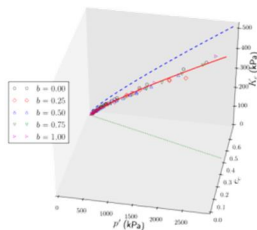


Figure 8. Unique 3D critical state line accounting for fabric anisotropy in sand (Zhao & Guo 2013)

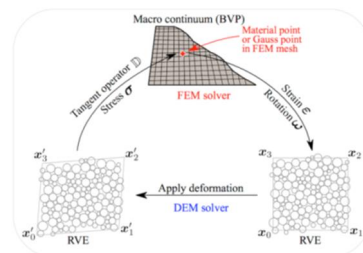


Figure 9. Hierarchical multiscale modelling of granular media by FEM-DEM coupling (Guo & Zhao 2014)

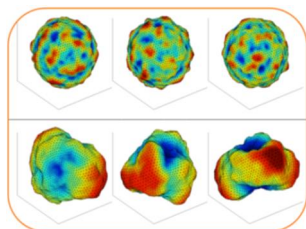


Figure 10. Generation of 3D sand grain particles based on Fourier shape descriptors and random fields theory (Mollon & Zhao 2014)

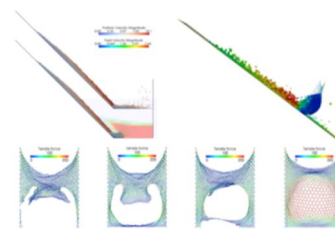


Figure 11. Coupled CFD-DEM modeling of debris flow impacting on flexible barrier (Zhao & Shan 2013)

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## Research highlights

### Hong Kong University of Science and Technology (HKUST) Geotechnical Group (Con't)

Prof. Gang Wang, Associate Professor

Website: <http://ihome.ust.hk/~gwang>



Gang Wang is Associate Professor in Geotechnical Engineering. His research interests include geotechnical earthquake engineering, soil dynamics, computational geomechanics and micromechanics. He has been actively developing constitutive models and computational methods for dynamic soil-structure interaction analyses and soil liquefaction simulation. His recent efforts aim at advancing fundamental understanding of cyclic mobility and post-liquefaction behaviour of granular soils from micromechanical perspectives, in particular, the evolution of particle-void structure and contact fabric during these processes. On the other hand, he developed innovative

ground motion characterization, modification and simulation techniques to improve understanding of earthquake impact on nonlinear structures and geotechnical systems. Most recently, he has been working on region-scale simulation of ground motions considering 3D topography and subsurface soil conditions, as well as earthquake scenario simulation in congested urban environment, with an overarching goal to improve seismic resilience of infrastructure in megacities.

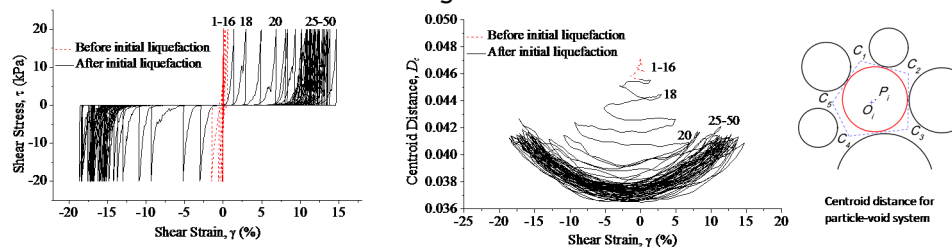


Figure 12. Microstructure evolution in cyclic mobility and post-liquefaction of sands (Wang & Wei 2016)

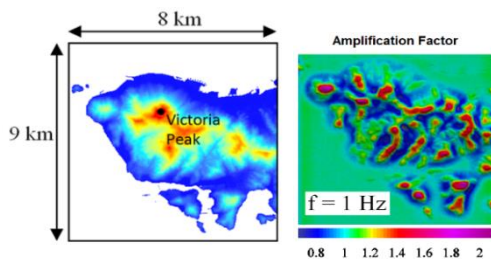


Figure 13. Region-scale ground motion simulation considering 3D topography and subsurface soil conditions using Hong Kong island as a testbed

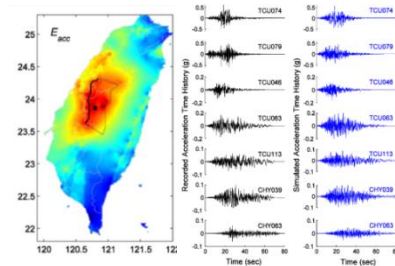


Figure 14. Ground motion simulation, modification using wavelet packets (Huang & Wang 2015)

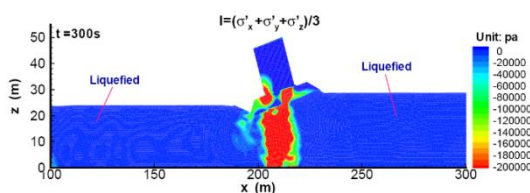


Figure 15. Nonlinear simulation of offshore breakwater on liquefied seabed (Ye, Huang & Wang 2016)

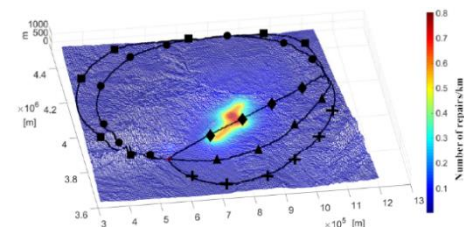


Figure 16. Path optimization of submarine cable through earthquake zone

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## Research highlights

### Hong Kong University of Science and Technology (HKUST) Geotechnical Group (Con't)

Prof. Jui-Pin Wang, Assistant Professor

Website: <http://ihome.ust.hk/~jpwang/>



Prof. JP Wang obtained his B.S. and M.S. from National Taiwan University, and Ph.D. from Columbia University. JP's research mainly focuses on reinforced soil structures and geotechnical reliability assessment. Recent projects include the design of curved soil retaining walls and the assembly of geogrids from 3D printing, which are the topics of the 2016 Dongju Lee Memorial Lecture invited by Columbia University, and also the recipient of Third-Place Award of Falling Walls Lab Hong Kong, 2016. As to geotechnical reliability analysis, JP has been working on PGA-CAV joint probabilistic seismic hazard analysis, from the theory of copula probability models.

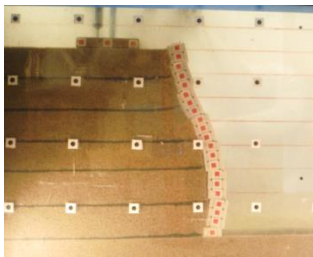


Figure 17. 1-g test

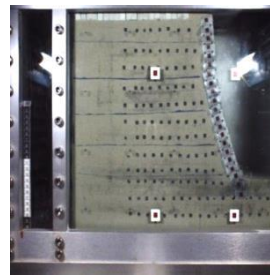


Figure 18. Centrifuge test

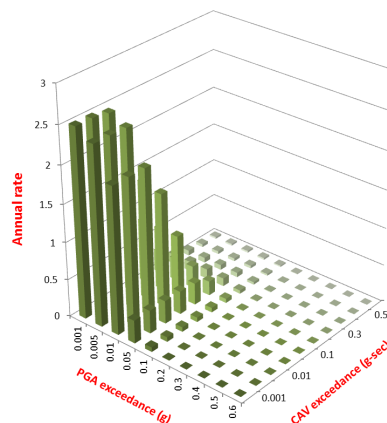


Figure 19. PGA-CAV "hazard plane" for Taipei

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## Research highlights

### Hong Kong University of Science and Technology (HKUST) Geotechnical Group (Con't)

Prof. Clarence Choi, Research Assistant Professor



Dr Choi obtained his Bachelor of Science in Civil Engineering at the University of Calgary (with distinction) and his PhD from the Hong Kong University of Science and Technology (HKUST). Dr Choi spent time in industry at Golder Associates Ltd. (formerly Geotechnical Consulting Group) working on landmark projects in Hong Kong including the Western Kowloon Terminus and the Third Runway for the Hong Kong International Airport. Upon returning to HKUST, he was appointed as Research Assistant Professor and a Junior Fellow of the HKUST Jockey Club Institute for Advanced Study.

The research of Dr Choi focuses on physical and numerical modelling of fundamental impact mechanisms of subaerial and subaqueous debris flows. He has expertise in centrifuge, flume, and large-scale impact modelling. Dr Choi has delivered several keynotes and invited talks internationally. Dr Choi also serves as committee members for the Association of Geotechnical and Geoenvironmental Specialist and a Task Force for the Hong Kong Institution of Engineers.

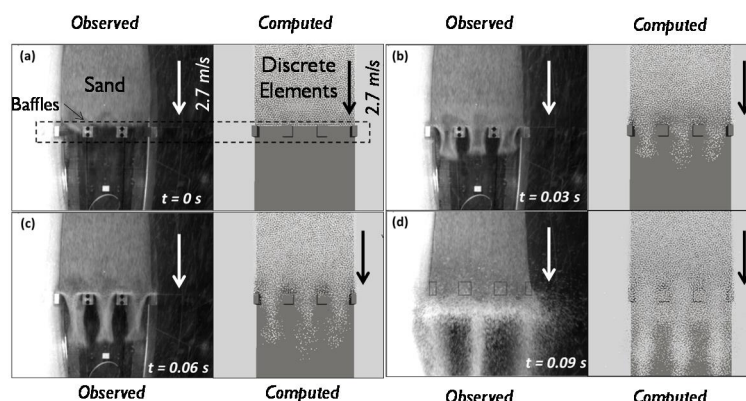


Figure 20. Comparison between observed and computed kinematics for flow-baffle interaction

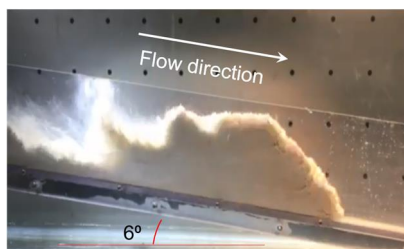


Figure 21. Physical modelling of submarine debris flow

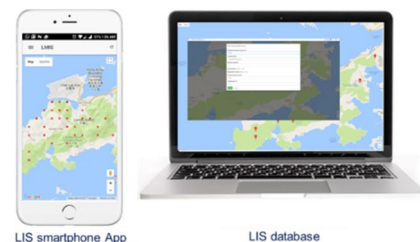


Figure 22. Smart landslide information system

#### Flume and discrete element modelling of interaction between debris flow and structures

- Choi, C.E., Ng, C.W.W., Song, D., Kwan, J.S.H., Shiu, H.Y.K., Ho, K.K.S. & Koo, R.C.H. (2014a). Flume investigation of landslide debris baffles. *Canadian Geotechnical Journal* **51**, No. 5, 540-533.
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## Research highlights

### Hong Kong University of Science and Technology (HKUST) Geotechnical Group (Con't)

Prof. Chao Zhou, Research Assistant Professor

Website: <http://www.ce.ust.hk/Web/FacultyStaffDetail.aspx?FacultyStaffId=93&Type=Faculty>



Dr Zhou is a Research Assistant Professor with expertise in constitutive modelling and advanced laboratory testing. His research focuses on cyclic thermo-hydro-mechanical behaviour of saturated and unsaturated soils, with applications to high-speed railway embankment and geo-energy problems such as energy pile and methane hydrate. In collaboration with Prof. Charles W.W. Ng, he developed a series of advanced test apparatus, including the first suction and temperature-controlled cyclic triaxial apparatus. Using the new apparatuses, he investigated thermal effects on various aspects of soil behaviour, such as volumetric and deviatoric soil deformations induced by thermal cycles, suction and thermal effects on cyclic shear behaviour. Moreover, Dr Zhou developed some new constitutive models with unique ability to better capture the complex behaviour of soil under cyclic thermo-hydro-mechanical loads.



Figure 23. Temperature and suction controlled cyclic triaxial apparatus (Ng & Zhou 2014)

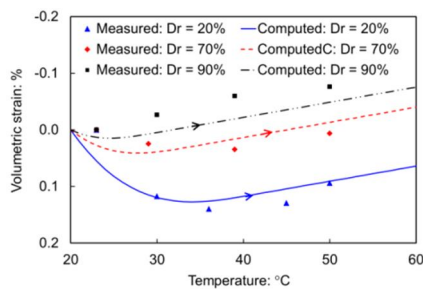


Figure 24. Measured and computed thermal strains of coarse-grained soil (Zhou *et al.* 2017)

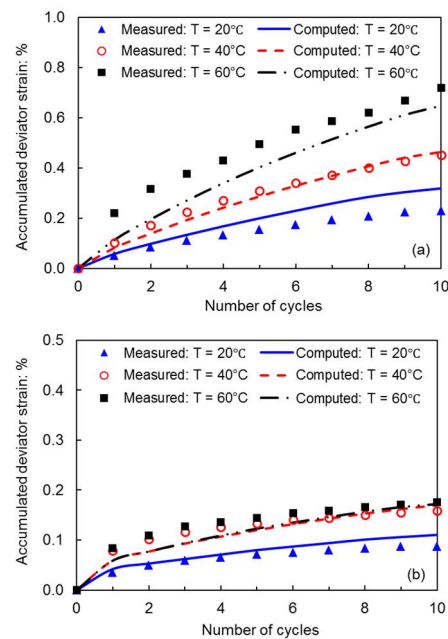


Figure 25. Measured and computed cyclic shear behaviour at various temperatures and at suction of (a) 0 kPa; (b) 30 kPa (Zhou & Ng 2016)

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## Research highlights

### Hong Kong University of Science and Technology (HKUST) Geotechnical Group (Con't)

#### 3. Facilities

##### 3.1. Geotechnical Engineering Laboratory

The geotechnical engineering laboratory of HKUST is equipped with numerous advanced testing apparatuses, most of which are developed by the geotechnical group of HKUST. Each apparatus has its own uniqueness, beneficial to the cutting-edge fundamental research of the geotechnical group. The following are examples of special equipment developed in this laboratory.

##### 3.1.1. Advanced testing apparatuses for unsaturated soil

Extensive advanced apparatuses are developed for testing unsaturated soil, including full-suction triaxial apparatus and direct shear box, one-dimensional instantaneous soil permeability apparatus, stress controlled pressure plate extractor (1D and 3D), and double cell volume measuring system. These apparatuses are used to investigate unsaturated soil behaviour with various applications, e.g., loose fill slopes in Hong Kong, expansive soil slope stability in the South-North Water Transfer Project, high-speed railway embankments and landfill covers. The above mentioned apparatuses have also been awarded patents. In particular, the double cell volume measuring system was adopted by the manufacturer GDS and is now a standard method to measure the volume change of unsaturated soils. It has been adopted by over 100 universities and scientific institutions.



Figure 26. Full suction triaxial apparatus (Ng & Menzies 2007)



Figure 27. Full-suction direct shear box for unsaturated soil (Ng 2014)



Figure 28. Stress-dependent 1D soil column (Ng & Leung 2011)



Figure 29. Stress-controlled 1D pressure plate (Ng & Pang 2000)



Figure 30. Stress-controlled 3D pressure extractor (Ng *et al.* 2012)

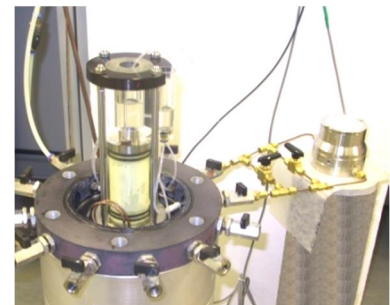


Figure 31. Double cell total volume measuring system (Ng *et al.* 2002)

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### Hong Kong University of Science and Technology (HKUST) Geotechnical Group (Con't)

#### 3.1.2. Temperature-controlled testing apparatuses

Various apparatuses are equipped with heating and cooling system, which are able to control soil temperature in a wide temperature range of  $-10$  to  $80^{\circ}\text{C}$ . Using these thermal apparatuses, the cyclic thermo-mechanical behaviour of saturated and unsaturated soils are systematically investigated, with application to energy pile, high-speed railway embankment, landfill cover and frozen ground.



Figure 32. Temperature controlled cyclic triaxial cell (Ng & Zhou 2014)



Figure 33. Temperature controlled double cell triaxial cell (Ng *et al.* 2016a)

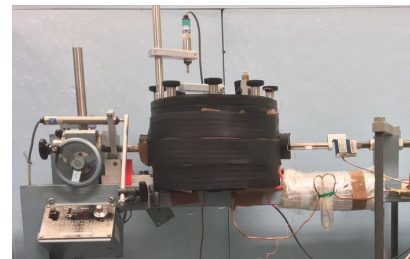


Figure 34. Temperature controlled direct shear box (Ng *et al.* 2017)

#### 3.1.3. Advanced apparatuses enabling complex loading conditions

This laboratory has a hollow cylinder torsional shear device and true triaxial apparatus. Compared with the conventional triaxial apparatus, these apparatuses are much more versatile and powerful. They are used to simulate many complex loading conditions for constitutive model verifications as well as to test soil behaviour under various field loading conditions such as seismic loading, wave loading and traffic loads.

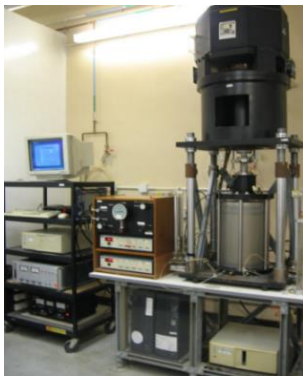


Figure 35. Hollow cylinder torsional shear device (Yang *et al.* 2007)

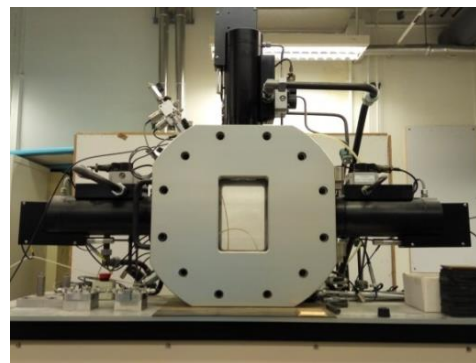


Figure 36. True triaxial apparatus

#### 3.1.4. Mechanical and electromagnetic wave-based characterizations of soil properties

Mechanical and electromagnetic wave-based systems are developed to investigate the anisotropic soil stiffness, which is important for analysing ground response under dynamic loads and the serviceability of civil engineering structures. Some examples are given here: (a) Resonant column designed to determine shear moduli and damping ratios of soil specimens at small strains; (b) Unsaturated triaxial apparatus equipped with three pairs of bender elements for measuring anisotropic stiffness; (c) True triaxial apparatus with bender element system and I-scan system (tactile pressure sensors) for multi-purposes,



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e.g., measuring stiffness and associated anisotropy changes during soil aging, monitoring the evolution of contact forces during the aging process; (d) Multi-functional oedometer cell with mechanical and EM wave-based sensing system for characterizations of soil behaviour, e.g., monitoring the formation of clay fabric associations during the sedimentation process, and characterizing clay fabric associations using the spectral dielectric responses.

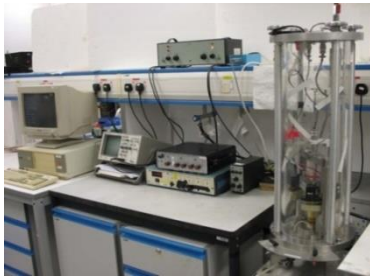


Figure 37. Energy-injecting virtual mass resonant column (Li *et al.* 1998)

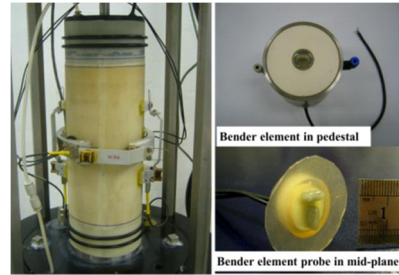


Figure 38. Bender element for measuring anisotropic stiffness (Ng & Yung 2008)

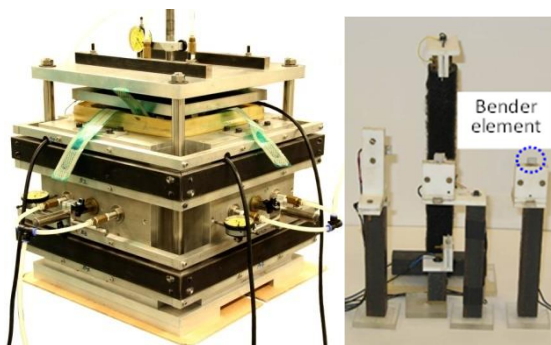


Figure 39. True triaxial apparatus with bender element and I-scan system (Wang *et al.* 2016)

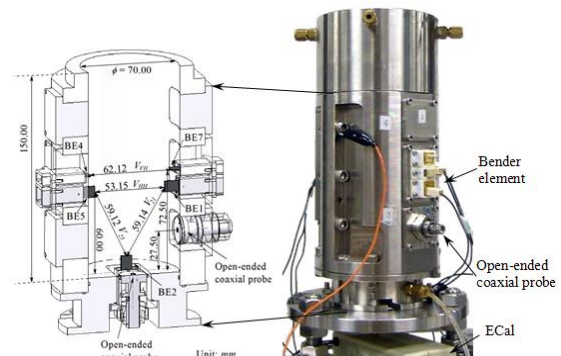


Figure 40. Multi-functional oedometer cell (Wang & Dong 2008)

#### 3.1.5. Geotechnical testing based on 3D printing technique

The geotechnical group in HKUST benefits from the application of 3D printing techniques on innovation of geotechnical testing devices and sensing techniques. Examples include (a) A biaxial system with flexible boundaries is designed to characterize the features of particle motion and associated contact movement in response to shearing, using the particle image velocimetry (PIV) technique. The 3D printing technique is applied to ease manufacture of the testing device and testing sample with very high accuracy. (b) 3D printed portable oedometer and tailor-made oedometer ring with a needle probe to measure pore water pressure and film-like sensor to measure  $K_0$ .

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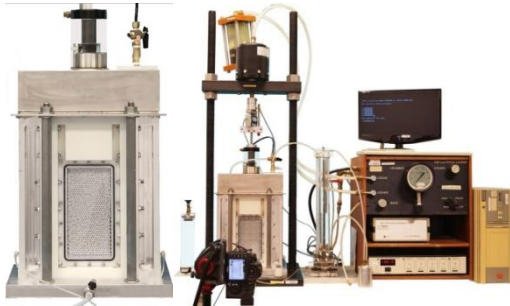


Figure 41. Biaxial system with flexible boundaries (Yuan *et al.* 2016)

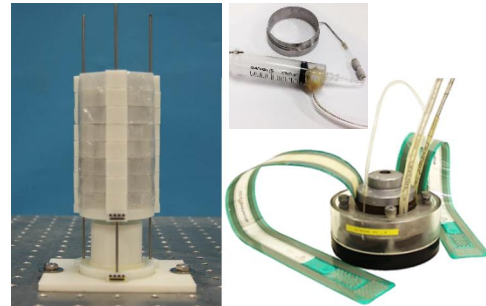


Figure 42. 3D printed portable oedometer with film-like sensors and the needle probe (Chow and Wang 2017; Gao *et al.* 2017)

#### 3.1.6. Geo-environmental room

The geo-environmental room (4 m × 4.5 m × 2.8 m) is designed to control various atmospheric parameters, including air temperature, relative humidity, rainfall intensity and light intensity within a particular waveband favourable for plant photosynthesis and plant growth. This room is adopted to investigate the mechanisms of atmosphere-plant-soil interactions. The results provide a scientific basis for a wide range of applications, such as the stabilization of shallow slope, erosion control, design of earthen landfill cover, phytoremediation, and promoting the growth of Chinese medicinal plants.



Figure 43. Geo-environmental room (Ng *et al.* 2016b)



Figure 44. Soil conditioning for promoting the growth of Chinese medicinal plants (e.g. ginseng)

#### 3.1.7. Apparatuses for studying internal erosion and surface erosion

The stress-controlled internal erosion testing apparatus control hydraulic gradient and stress state independently. It allows a systematic investigation of the initiation and development of internal erosion subjected to complex stress states. In addition, a great benefit of this apparatus is its capability to investigate the stress-strain behaviour of the soil immediately after the internal erosion test. The Jet index erodibility test apparatus was modified from the ASTM standard D5852-00 apparatus, to allow testing the erodibility of relatively coarse soils and to eliminate turbulent effects of water inflow. The apparatus provides an important means for investigating the initiation of debris flows, soil and water conservation, and sediment transport.

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Figure 45. Stress-controlled internal erosion testing apparatus (Chang & Zhang, 2011)



Figure 46. Jet index erodibility testing apparatus (Chang *et al.* 2011)

#### 3.1.8. Physical models with innovative instrumentations

Various physical models with innovative instrumentations are built. The first example is a water flume with innovative instrumentation. In particular, low-cost and small-size MEMS (Micro-Electro-Mechanical-Systems) accelerometers and a MEMS sensing package, termed the Smart Soil Particle (SSP, first generation), is used to monitor movements of the slope body. Another example is a new pressure chamber with advanced sensing devices for model pile test. It allows for characterizing stress evolution in the soil surrounding the model pile during pile installation and setup, using the tactile pressure sensors and mechanical wave-based tomography imaging.



Figure 47. Water flume with Smart Soil Particle (Ooi *et al.* 2014)



Figure 48. Pressure chamber with advanced sensing devices for model pile test (Zhang & Wang 2015)

#### 3.1.9. Data-enabled Scalable Research Laboratory

The Data-enabled Scalable Research Laboratory (DESR Lab) is the Makerspace specialized in the applications of Geotechnical Internet of Things (Geo-IoT), Deep Learning, and Big Data Analytics on the sustainable city development, e.g., critical infrastructure monitoring and slope health monitoring, and an open platform for geotechnical industries to collaborate and share resources.

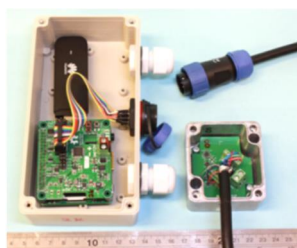


Figure 49. Smart Soil Particle sensor for slope health monitoring (Geo-IoT sensor node)



Figure 50. The Smart Soil Particle installed at field



Figure 51. Big data server farm at the DESR Lab.



## Research highlights

### Hong Kong University of Science and Technology (HKUST) Geotechnical Group (Con't)

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## Research highlights

### Hong Kong University of Science and Technology (HKUST) Geotechnical Group (Con't)

#### 3.2 Geotechnical Centrifuge Facility

The Geotechnical Centrifuge Facility (GCF) at the Hong Kong University of Science and Technology (HKUST) is an advanced laboratory for physical modelling of a wide-range of engineering problems. The focus of the GCF is the beam centrifuge which has a diameter of 8 m and a capacity of 400g-ton (Figure 52). The GCF was established in 2001 and serves the geotechnical community internationally and in Hong Kong. Since its establishment, The GCF has contributed significantly to the advancement of scientific knowledge in the geotechnical field. The GCF is managed by a senior engineer who oversees operations and is essential to the development of new equipment. Research topics include rainfall-induced landslides, consolidation of reclaimed lands, seismic-induced liquefaction, tunnelling, deep excavations, piles and other soil-structure interaction problems. More recent research directions include investigating the behaviour of energy piles in both clay and sand, climate effects on embankments and slopes, the response of off-shore structure to wave loading and the interaction of debris flow with structures. In this section the senior engineer is introduced first, where after the state-of-the-art equipment used in the GCF is presented (Figures 57 - 63).

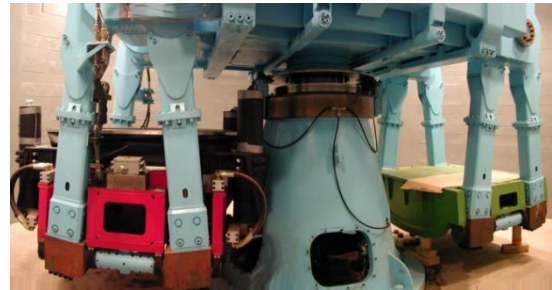


Figure 52. HKUST geotechnical centrifuge

#### 3.2.1. Senior Engineer

Dr Paul Van Laak



Dr Van Laak obtained his Bachelor of Science Degrees in Civil Engineering and Mechanical Engineering at Union College in 1981 and his Master of Science degree at Union in 1982. While working as the Instrumentation Research Engineer at the Rensselaer Polytechnic Institute Department of Civil and Environmental Engineering he earned his Ph.D. in Civil Engineering in 1994. He has over 35 years of experience in design and development of instrumentation for Geotechnical research and has collaborated with dozens of educational, governmental and commercial clients around the world to manufacture new and innovative experimental equipment and methods for use in laboratory and field testing. As Senior Engineer at HKUST, he advises and supports doctoral students, post-docs, clients and faculty in design of experiments, development of advanced instrumentation, and development of new and innovative experimental techniques.



Figure 53. Biaxial centrifuge shaker for seismic simulations using the geotechnical centrifuge



Figure 54. Biaxial laminar container for use with the biaxial centrifuge shaker

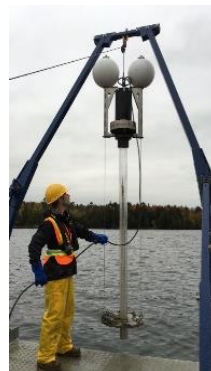


Figure 55. Vibracore sediment for collection of offshore sediments



Figure 56. Miniature cone penetrometer for geotechnical centrifuge model testing

## Research highlights

### Hong Kong University of Science and Technology (HKUST) Geotechnical Group (Con't)

#### 3.2.2. State-of-the-art equipment

- **Bi-axial (2D) shaking table:** The centrifuge is equipped with the world's first bi-axial shaking table. The shaking table is capable of simulating earthquake motions up to 7 Hz (prototype) in two horizontal directions simultaneously. The shaker can accommodate a model size of up to 3000 N and can operate at up to 75g for dynamic testing.
- **Four-axis (4D) robotic manipulator:** The state-of-the-art four-axis robotic manipulator has a tool changer and four tool adopters to permit interchangeable tools without having to stop the centrifuge. At a centrifugal acceleration of 100g, the robotic manipulator can produce torque of up to  $\pm 5$  MN·m and handle prototype loads of up to 50 MN.
- **Centrifuge environmental chamber (CEC):** The CEC is a self-contained patented tool which allows in-flight simulation of various atmospheric conditions during centrifuge testing. Variables that can be controlled include temperature (15 - 50°C), relative humidity (30 - 100%), solar radiation ( $\pm 250$  - 1550 W/m<sup>2</sup>), wind speed (0.2 - 5 m/s model) and rainfall (15 - 100 mm/hr prototype). The CEC has the unique capability of allowing independent control of the climate variables, and thus allowing for the simulation of more diverse atmospheric paths. The independent control means more fundamental studies on the influence of climate variables on geotechnical infrastructure are possible. In addition, being able to control the relative humidity allows more detailed studies on unsaturated soil behaviour. Future plans include redesigning the cooling system to simulate sub-zero temperatures for frost conditions.
- **Environmental Hydrodynamic Loading System (EHLS):** The EHLS has the capability to model a wide range of offshore geotechnical problems, such as foundations for offshore wind farms, subsea pipelines etc. Two types of wave generators are included: 1) Piston Wave Generator for modelling shallow water coastal waves, and 2) Flap Wave Generator for modelling deep ocean waves. A frequency response exceeding 100 Hz can be simulated. This enables prototype waves having short and long periods. The maximum displacement of the plate is 10 cm. Different waveforms can be used as input (i.e. sine, cosine, square, triangular and linearly varying patterns) to generate various fluid wave types. To make the EHLS applicable to a wider range of offshore geotechnical issues, the depth of the soil layer can be varied up to maximum of 30 cm (model dimensions). Wave reflections are addressed by a passive-type wave absorbing system placed at the reflecting end of EHLS.



Figure 57. Bi-axial (2D) shaking table (Ng *et al.* 2004)



Figure 58. Four-axis (4D) robotic manipulator (Ng *et al.* 2002)

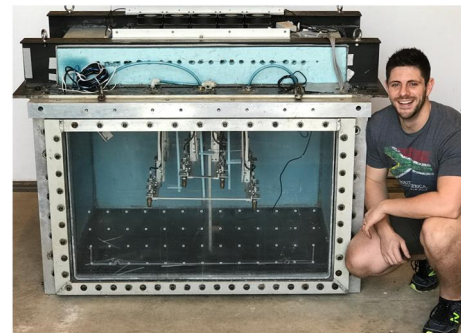


Figure 59. Centrifuge environmental chamber (Archer & Ng 2016)

## Research highlights

### Hong Kong University of Science and Technology (HKUST) Geotechnical Group (Con't)

- **Energy pile heating-cooling system:** The heating and cooling system was developed to facilitate in-flight testing of model energy piles. The system is able to control the temperature in an energy pile between 3°C and 90°C. The temperature is controlled by circulating a heat-exchange fluid with varying temperature inside the model pile.
- **Debris flow flexible barrier model:** This model barrier is the first in the world to capture the prototype response of a flexible barrier for resisting debris flows and rockfall (Ng *et al.* 2016b). The flexible barrier adopts a patented bilinear spring system to attenuate impact loading. The spring systems are highly variable, and repeatable.
- **7-m long channel:** The 7-m channel is a new addition to GCF. It is capable of modelling a wide range of subaerial (onshore) and subaqueous (offshore) debris flows. The 7-m channel can model a debris volume of up to 1 m<sup>3</sup> and its surrounding tank can simulate up to 40 m<sup>3</sup> of ambient fluid. The channel can be used to study fundamental flow mechanisms and flow interaction with structures (Choi *et al.* 2016, Ng *et al.* 2016d).

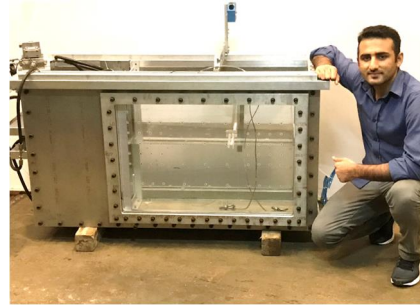


Figure 60. Environmental Hydrodynamic Loading System

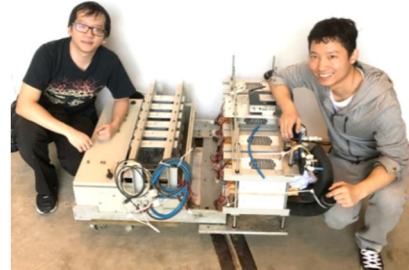


Figure 61. Energy pile heating-cooling system (Ng *et al.* 2014; 2016a)

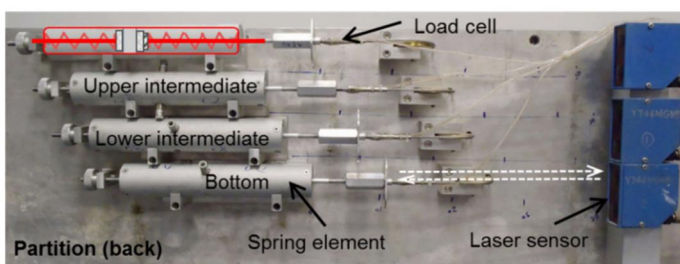


Figure 62. Flexible barrier model (Ng *et al.* 2016c)



Figure 63. 7-m long subaerial and subaqueous debris flow model



## Research highlights

### Hong Kong University of Science and Technology (HKUST) Geotechnical Group (Con't)

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## Research highlights

### Hong Kong University of Science and Technology (HKUST) Geotechnical Group (Con't)

#### 4. Major research projects

4.1. Understanding Debris Flow Mechanisms and mitigating Risks for a Sustainable Hong Kong (Theme-based Research Scheme Project funded by the Research Grants Council of Hong Kong, T22-603-15/N)



**Coordinating Institution:** the Hong Kong University of Science and Technology (HKUST)

**Participating Institutions:** the University of Hong Kong (HKU), City University of Hong Kong (CityU), the Institute of Mountain Hazards of the Chinese Academy of Sciences (IMHE), Hong Kong Institution of Engineers (HKIE); the University of Cambridge; and the Norwegian Geotechnical Institute (NGI)

**Project Coordinator:** Prof. Charles W.W. Ng (HKUST)

**Co-principal Investigators:** Prof. Cui Peng (IMHE of CAS); Mr. W.K. Pun (HKIE); Prof. Limin Zhang (HKUST); Prof. Wang Yu (CityU)

**Co-Investigators:** Dr. Sergio Lourenco (HKU); Prof. Malcolm Bolton (the University of Cambridge); Dr. Billy Hau (HKU); Prof. Suzanne Lacasse (NGI); Dr. Julian Kwan (HKIE); Prof. Gang Wang (HKUST); Prof. Jidong Zhao (HKUST); Prof. Yu-Hsing Wang (HKUST); Prof. Jui-Pin Wang (HKUST); Prof. Gordon Zhou (IMHE)

#### 4.1.1. Background

As human development encroaches upon hillsides in densely-populated cities, such as Hong Kong, and extreme rainfall events occur with increasing frequency due to climate change, the danger posed by landslides will inevitably increase. The real global threat posed by landslides is reflected in the landslide disasters that occurred in Hong Kong, which resulted in the closure of the sole transportation corridor to the airport for 16 hours (Figure 64) or the debris flow in Hiroshima, Japan, which resulted in 74 fatalities and the destruction of 133 homes (Figure 65). It is evident that there is an urgent need to enhance our understanding and mitigate this destructive natural phenomenon.



Figure 64. Debris flow obstructing Cheung Tung Road on Lantau Island, Hong Kong



Figure 65. 2014 Debris flow in Hiroshima, Japan (Getty Images)

In light of the pertinent danger associated with debris flows, the Department of Civil and Environmental Engineering of HKUST, under the leadership of Professor Charles W. W. Ng, was recently awarded a landmark grant from the Research Grants Council of Hong Kong for a Theme-based Research Scheme project named “*Understanding Debris Flow Mechanisms and Mitigating Risks for a Sustainable Hong Kong*”.

## Research highlights

### Hong Kong University of Science and Technology (HKUST) Geotechnical Group (Con't)

#### 4.1.2. Project mission

The project mission aims to advance our scientific understanding of debris flow dynamics and the interaction between debris flows and multiple flexible barriers. The success of this project will see a reduction in the environmental impacts and costs of mitigation measures against debris flows for the safe and sustainable development of Hong Kong.

#### 4.1.3. About this project

This innovative project comprises three technical components, specifically (i) debris flow mechanics; (ii) risk assessment; and (iii) debris flow mitigation. Debris flow mechanics (led by Prof. Matthew Coop of University College London) entails material characterisation of debris flow using micro and macro-approaches (Yang *et al.* 2016; Wang & Akeju 2016; Cao *et al.* 2016; Aladejare & Wang 2016) and field monitoring at the Jiangjia Ravine in Kunming, China. Risk assessment (led by Prof. Limin Zhang of HKUST) focuses on adopting innovative monitoring techniques such as unmanned aerial vehicles and smart soil particles (Gao *et al.* 2016) to develop a new generation of reliability-based debris flow vulnerability models. Debris flow mitigation (led by Prof. Charles W.W. Ng of HKUST) focuses on studying debris flow interaction with multiple flexible barriers using a multi-scale physical modelling (Choi *et al.* 2016; Ng *et al.* 2016b; 2016c; 2017a; 2017b) and developing world-leading guidelines (Koo *et al.* 2016a; 2016b) on multiple flexible barriers.

Key highlights of this project include the development of world-class facilities to model debris flow interaction with barriers. These state-of-the-art facilities include (i) a pendulum impact facility in Shenzhen, China (Figure 66); (ii) a large-scale 20-m-long flume model at the Kadoorie Centre, Hong Kong (Figure 67); and (iii) a full-scale 120-m-long flume model in Kunming, China (Figure 68). The 120-m flume is also a collaborative research project between HKUST and IMHE of the Chinese Academy of Sciences. It will have a channel width of 8 m to facilitate the installation of full-scale barriers and model up to 500 m<sup>3</sup> of debris. Extensive feedback was received from the international community, more specifically Dr. Richard Iverson from the United States Geological Survey (Figure 69), Dr. Brian McArdell of the Swiss Federal Institute for Forest, Snow, and Landscape Research (WSL), and Prof. Chan Young Yune from Gangneung-Wonju National University of Korea (Figure 70). All of these pioneering physical modelling facilities will be of paramount importance in revealing the fundamental interaction mechanisms between debris flow and barriers and help to deliver the project deliverables and to make an impact internationally.

In addition to physical modelling and risk and reliability (Zhang & Zhang 2016), this project will also rely on the expertise of Prof. Jidong Zhao and support of Prof. Gang Wang of HKUST, to develop a novel Computational Fluid Dynamics (CFD) model coupled with a Discrete Element Method model (DEM) (Wei & Gang 2016; Guo and Zhao 2016; Zhao *et al.* 2016) capable of modelling different particle shapes and considering changes in fluid viscosity based on changes in fines content of the interstitial fluid. Furthermore, findings from this project will be incorporated into a new course, first of its kind, to provide students and practitioners with the necessary training to understand the complex natural phenomenon of debris flow.



Figure 66. Pendulum impact facility (Ng *et al.* 2016a)



Figure 67. 20-m flume in Hong Kong

## Research highlights

### Hong Kong University of Science and Technology (HKUST) Geotechnical Group (Con't)



Figure 68. 120-m flume in Kunming, China

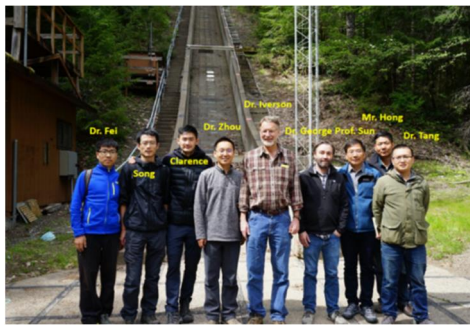


Figure 69. Field visit to USGS flume facility in Oregon, USA.



Figure 70. Field visit to Jiangjia Ravine in Kunming, China (from left: Prof. Chan Young Yune; Mr. Desmond Cheung (PhD student); Mr. George Goodwin (PhD student); Prof. Gordon Zhou; and Dr Clarence Choi)

#### 4.1.4. Looking ahead

The success of this project will have an immediate effect on the local industry practice and will lead to sustainable mitigation measures, enhanced cost effectiveness and more environmentally-friendly work in Hong Kong and elsewhere in the world. This project commenced in Jan. 2016 and had its first international technical advisory meeting on 26 November 2016 (Figures 71 and 72). We hope to share our findings from this project with the geotechnical community in due course.



Figure 71. Prof. Charles Ng (far left) engaged in discussion with Prof. Malcolm Bolton (far right) during the international advisory meeting



Figure 72. International advisory meeting: Prof. Suzanne Lacasse (top left); Prof. Oldrich Hungr (top middle); Prof. Andrew Malone (top right); Prof. Malcolm Bolton (bottom left); Prof. John Endicott (bottom middle); Mr. H.N. Wong (bottom right)



## Research highlights

### Hong Kong University of Science and Technology (HKUST) Geotechnical Group (Con't)

#### 4.1.5. Selected references

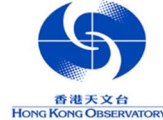
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## Research highlights

### Hong Kong University of Science and Technology (HKUST) Geotechnical Group (Con't)

4.2. Coping with landslide risks in Hong Kong under extreme storms: Storm scenarios, cascading landslide hazards and multi-hazard risk assessment (RGC Collaborative Research Project No. C6012-15G)



**Investigators:** Prof. Limin Zhang (PI, HKUST), Dr Raymond Cheung (GEO), Prof. Jimmy Jiao (HKU), Dr T.C. Lee (HKO), Prof. Charles W.W. Ng (HKUST), Prof. Y.K. Tung (HKUST) and Prof. Jidong Zhao (HKUST)

**International Advisors:** Prof. Peng Cui (CAS), Dr John Endicott (AECOM), Prof. D.G. Fredlund (USask), Prof. Suzanne Lacasse (NGI), Prof. C.F. Lee (HKU), Prof. Joseph Lee (HKUST), Ir Y.K. Shiu (GEO)

Slope failures in Hong Kong are frequently triggered by rainstorms. For example, a severe rainstorm hitting Lantau Island in June 2008 caused about 1,600 natural terrain landslides. If the same rainstorm were to hit Hong Kong Island, the current slope safety system would be stretched to its limit. The capacity of the system will be exceedingly overwhelmed upon more extreme rainfall. According to Hong Kong Observatory, the annual rainfall in Hong Kong is expected to be more variable and extreme over time under the changing climate. Under extreme rainfall conditions, multiple hazardous processes such as landslides, debris flows and flooding may occur simultaneously or sequentially, resulting in cascading hazards increasing the risk. In the worst cases, interactions among these hazards can generate new hazards of greater destructive power such as formation of landslide dams and dam breaching. It is important to identify catastrophic hazard scenarios that could be generated in Hong Kong, to identify the bottlenecks of the slope safety system, and to make recommendations for improved preparedness and system safety.

The primary objective of this project is to develop a stress-testing framework (Figure 73) for assessing the landslide risk in Hong Kong under extreme rainstorms caused by the changing climate. This project will, for the first time, address the issue of slope safety under extreme rainstorms within a novel framework of 'stress testing' by integrating the strengths of two universities (HKUST and HKU) and two government departments (Geotechnical Engineering Office and Hong Kong Observatory). Stress testing is defined as a targeted reassessment of safety margins of a given system in light of extreme events. It involves testing beyond normal operational capacity, often to a breaking point. The scientific tasks of this project will include (1) identification of future critical storm scenarios considering climate changes, (2) evaluation of slope system response under extreme rainstorms using advanced multi-scale hydrological and geotechnical processes modelling algorithms and advanced centrifuge modelling techniques, (3) multi-hazard risk assessment, and (4) formulation of a unique stress-testing framework for evaluating the Hong Kong slope safety system. The bottlenecks of the present Hong Kong slope safety system will be identified and recommendations for improvements to the slope safety system will be proposed for policy makers.

The proposed multi-scale multi-process modelling techniques will advance the state-of-the-art in hazard analysis (Figure 74). The stress-testing framework for landslide risk management can be applied to other regions of similar climate conditions and to other engineering systems.

## Research highlights

### Hong Kong University of Science and Technology (HKUST) Geotechnical Group (Con't)

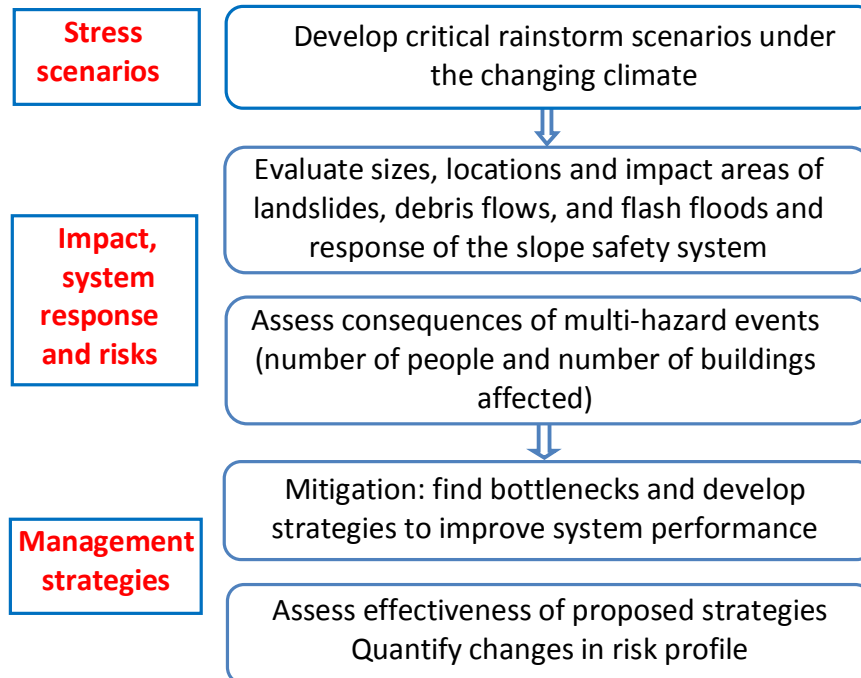


Figure 73. Proposed stress-testing framework for evaluating the Hong Kong slope safety system

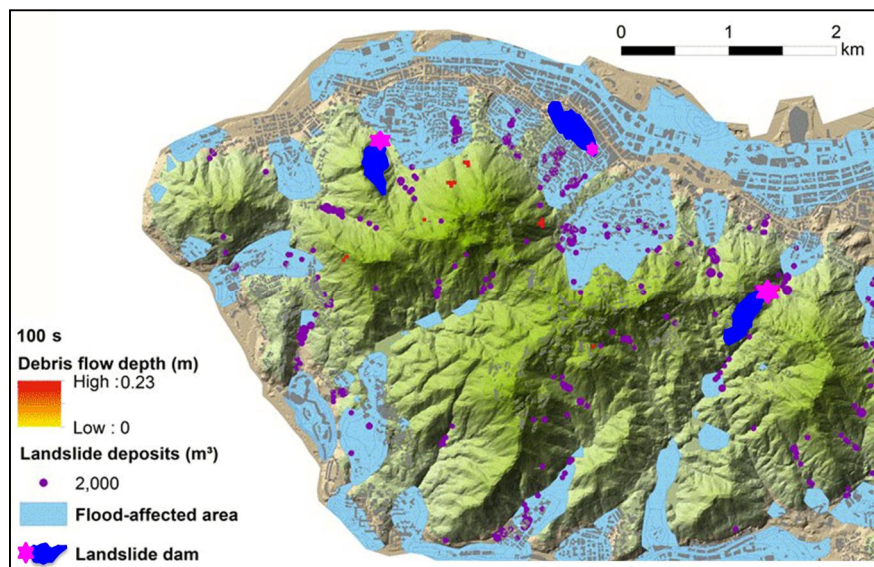
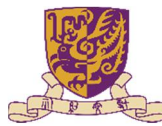


Figure 74. Shedding light on cascading hazards and their impact, expecting the “unexpected” using science

## Research highlights

### Hong Kong University of Science and Technology (HKUST) Geotechnical Group (Con't)

4.3. Green Slope Engineering for Hong Kong (RGC Collaborative Research Fund Project HKUST9/CRF/09)



**Coordinating Institution:** the Hong Kong University of Science and Technology (HKUST)

**Participating Institutions:** the University of Hong Kong (HKU), Chinese University of Hong Kong (CUHK)

**Investigators:** Prof. Charles W.W. Ng (PI, HKUST), Prof. Limin Zhang (HKUST), Prof. Yu-Hsing Wang (HKUST), Prof. George Tham (HKU), Prof. Ryan Yan (HKU), Prof. Billy Hau (HKU) and Prof. Lee Man Chu (CUHK)

**Local and International Advisory Committee:** Dr Cyril Chan (Instrumentation contractor), Ir Raymond Chan (Geotechnical Engineering Office of HKSAR), Dr John Endicott (Consulting Engineer), Dr C K Lau (Contractor), Dr Jack Pappin (Consulting Engineer), Ir Ringo Yu (Chairman of the Geotechnical Division Committee of HKIE), Prof. Bujang Huat (University of Putra, Malaysia) and Prof. Malcolm Bolton (Cambridge University, UK)

There has been an increasing demand from the public for environmentally friendly designs and for upgrading of slopes in Hong Kong in recent years. With Hong Kong's rugged topography and frequent rainstorms, landslides have always been an alarming problem. The prime objectives of this project are to investigate and improve our fundamental understanding of root-soil-water interactions and to develop an innovative and environmentally friendly reliability-based preliminary design framework for an "integrated bioengineered live slope cover" for shallow soil slopes in Hong Kong. This live cover will be self-regenerative and sustainable (almost maintenance free). Five major research tasks (Tasks A-E) will be carried out including field monitoring and root system characterization, centrifuge and numerical modelling of bioengineered slopes, development of an integrated quality assurance scheme and a preliminary reliability-based design methodology for bioengineered slopes. Findings from this project will provide new insights into the behaviour of bioengineered slopes in Hong Kong and the newly developed innovative reliability-based preliminary design guidelines will provide the basis for future laboratory simulations and field trials.

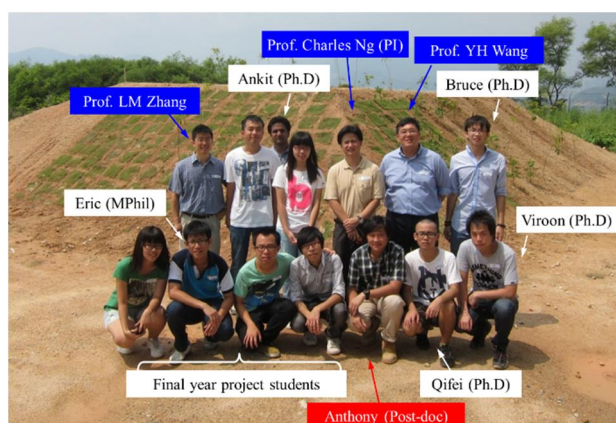


Figure 75. HKUST Green slope engineering research group

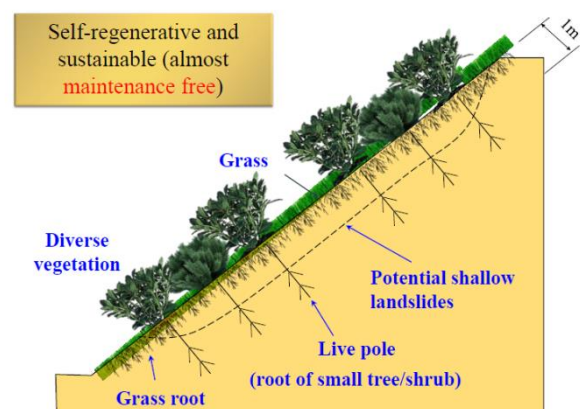


Figure 76. Bioengineered 'live' slope cover



## Research highlights

### Hong Kong University of Science and Technology (HKUST) Geotechnical Group (Con't)

#### Task A: Field Monitoring and Site Characterization

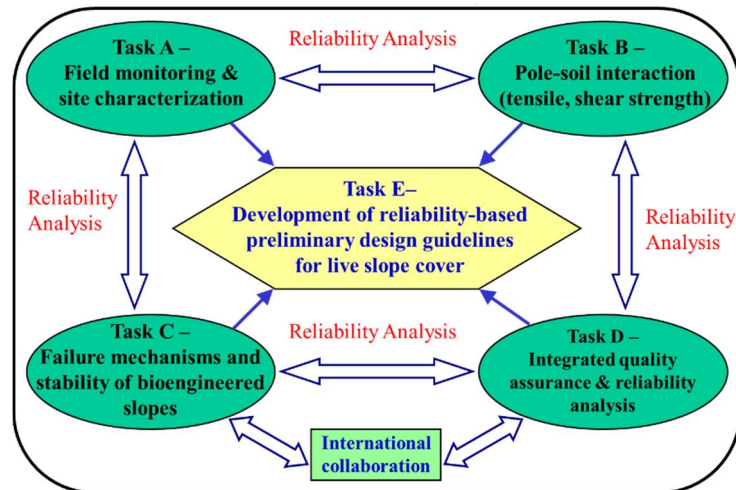


Figure 77. Research strategy

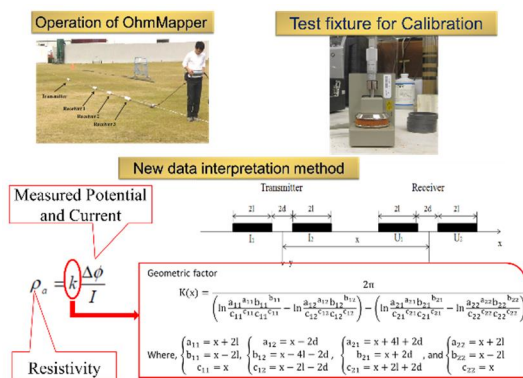


Figure 78. Instrumentation and new data interpretation method using OhmMapper (Niu & Wang 2013; Niu & Wang 2014)

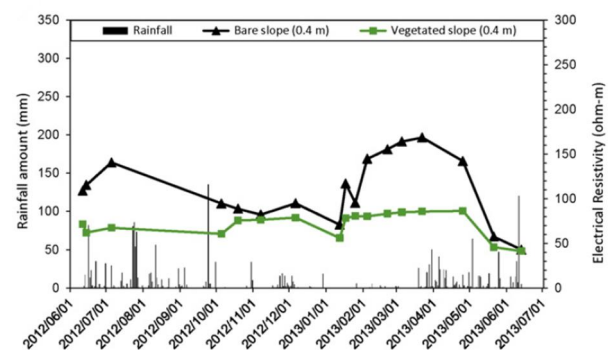


Figure 79. Seasonal variations in the soil resistivity measured by OhmMapper on vegetated slopes at a depth of 0.4 m (Niu *et al.* 2016)

#### HKUST Eco-Park

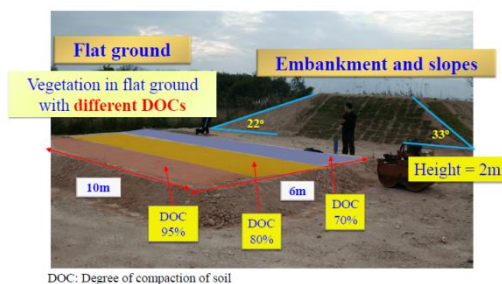


Figure 80. Site overview

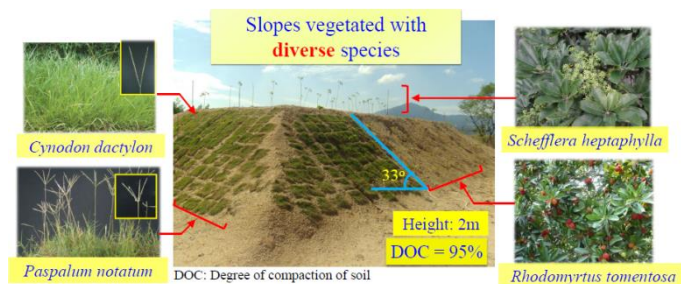


Figure 81. Vegetation in embankment and slopes (Garg *et al.* 2015; Leung *et al.* 2015)

## Research highlights

### Hong Kong University of Science and Technology (HKUST) Geotechnical Group (Con't)

#### Task B: Pole-Soil Interaction and Grass Root-Soil Interaction

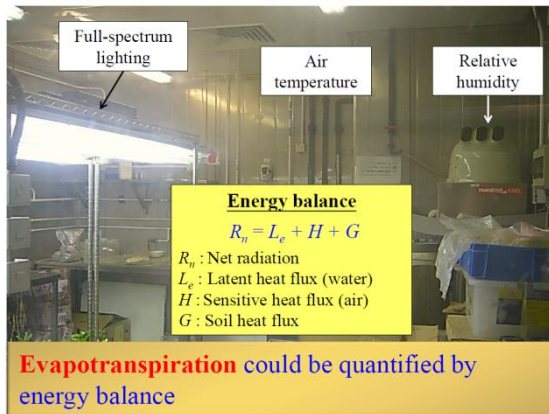


Figure 82. Atmospheric-controlled plant room (Garg *et al.* 2015b)

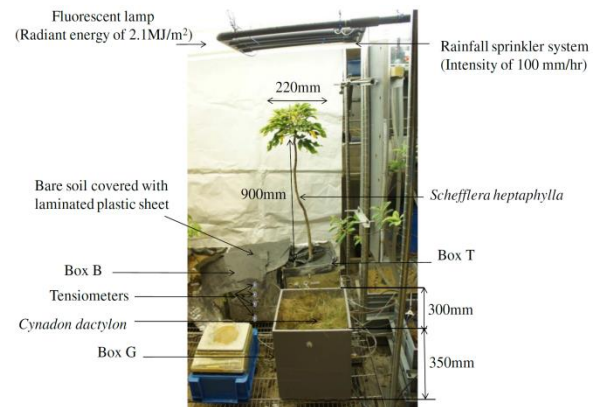


Figure 83. Overview of typical bare, grass and tree test boxes (Ng *et al.* 2014)

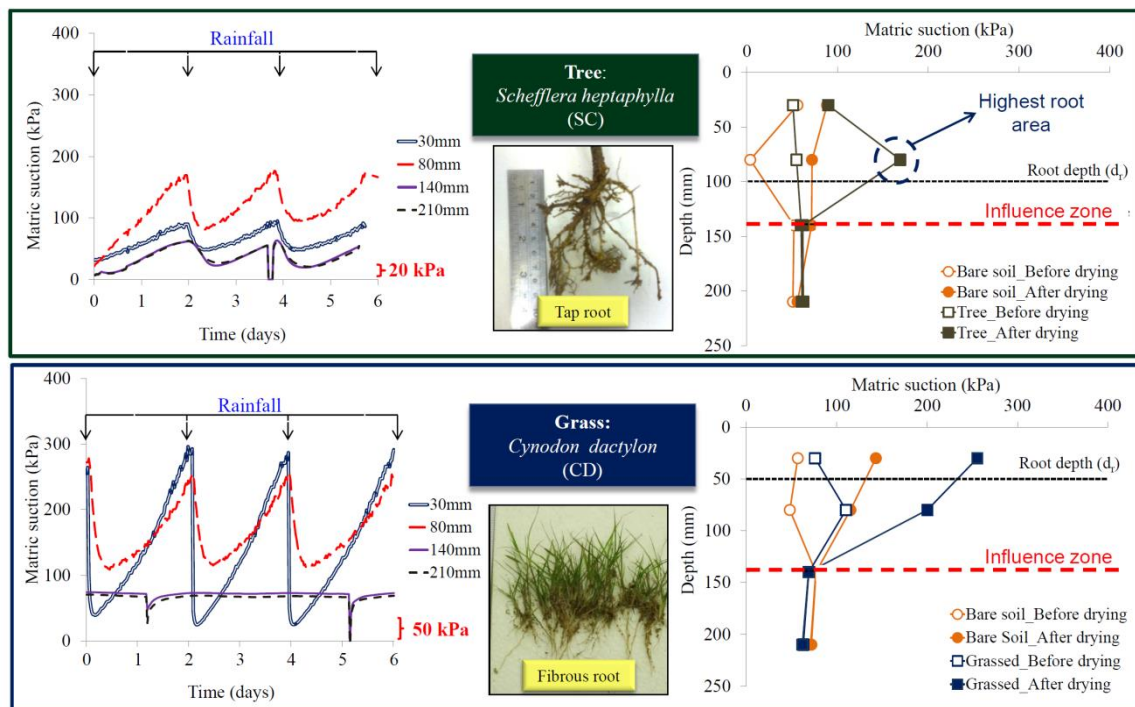


Figure 84. Effect of drying-wetting cycles on suction induced by plants (Ng *et al.* 2013; Ng *et al.* 2016a)

## Research highlights

### Hong Kong University of Science and Technology (HKUST) Geotechnical Group (Con't)

#### Task C: Investigation of Failure Mechanisms and Stability

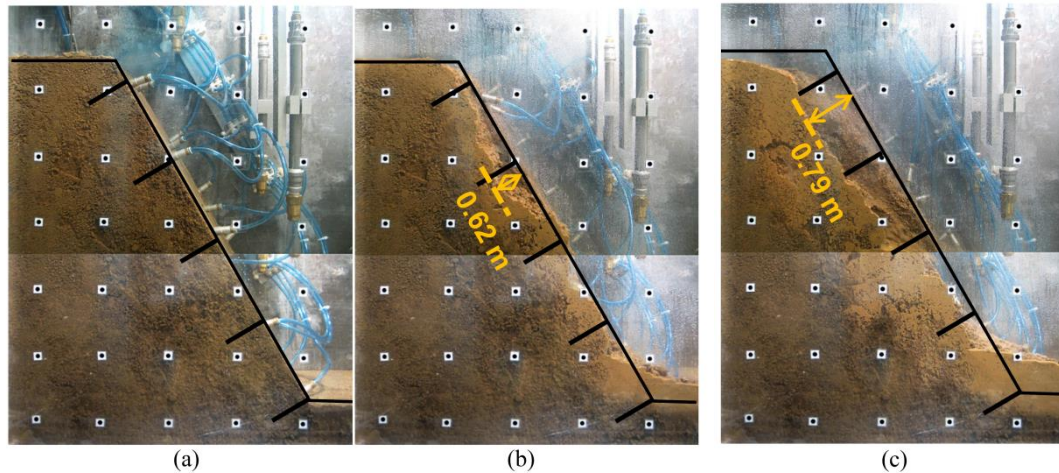


Figure 85. Failure mechanisms of a 60-degree slope reinforced with roots (a) before and after (b) 3 and (c) 5 hours of rainfall in the centrifuge (Ng *et al.* 2016b; Leung *et al.* 2017)

#### Task D: Integrated Quality Assurance and Reliability Analysis

##### Simulation of spatial variability of soil parameters

Parameters considered: permeability and its induced suction magnitude, soil strength parameters and root strength

$$R = f(k_s, \phi, c', p)$$

reliability-based optimization permeability suction cohesion root strength

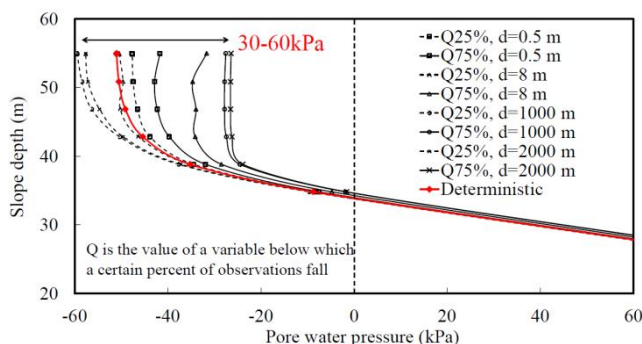


Figure 86. Effects of uncertainty of permeability function on the pore-water pressure distribution (Zhu *et al.* 2013)

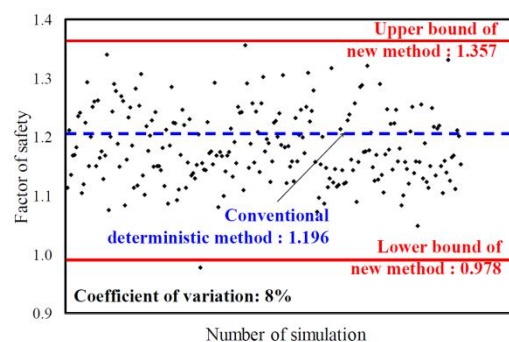


Figure 87. Effects of uncertainty of permeability function on slope stability (Zhu *et al.* 2013)



## Research highlights

### Hong Kong University of Science and Technology (HKUST) Geotechnical Group (Con't)

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## Research highlights

### Hong Kong University of Science and Technology (HKUST) Geotechnical Group (Con't)

4.4. Green Slope Engineering: Bioengineered, Live Cover Systems for Man-made Fill Slopes and Landfill Capillary Barriers in Hong Kong (RGC Collaborative Research Fund Project HKUST6/CRF/12R)



**Coordinating Institution:** the Hong Kong University of Science and Technology (HKUST)

**Participating Institutions:** the University of Hong Kong (HKU), Chinese University of Hong Kong (CUHK), Hong Kong Baptist University (HKBU)

**Investigators:** Prof. Charles W.W. Ng (PI, HKUST), Prof. Ming Hung Wong (Co-PI, HKBU), Prof. Limin Zhang (HKUST), Prof. Yu-Hsing Wang (HKUST), Prof. George Tham (HKU), Prof. Ryan Yan (HKU), Prof. Billy Hau (HKU) and Prof. Lee Man Chu (CUHK)

**Advisory Committee:** Dr Cyril Chan (Instrumentation contractor), Ir Raymond Chan (Geotechnical Engineering Office of HKSAR), Dr John Endicott (Consulting Engineer), Dr C K Lau (Contractor), Dr Jack Pappin (Consulting Engineer), Ir Ringo Yu (Geotechnical Division Committee of HKIE), Dr Johnny Cheuk (Consulting Engineer), Ir C F Lam (Environmental Protection Department), Ir John Cowland (Consulting Engineer)

The prime objectives of this project are to investigate and improve fundamental understanding of root-soil-water-gas-heat interactions and to develop an innovative and environmentally friendly reliability-based preliminary design framework for an “integrated bioengineered live cover for man-made fill slopes and landfill capillary barriers” in Hong Kong. A capillary barrier is an earth layered system, which makes use of unsaturated hydraulic characteristics of different types of soils to minimize rainfall infiltration and to drain away infiltrated water quickly. This live cover will be self-regenerative and sustainable (almost maintenance free). Five major research tasks will be carried out by a multi-disciplinary research team. The five research tasks are field monitoring and site characterization of man-made fill slopes and landfills, centrifuge and numerical modelling of bioengineered fill slopes and landfill capillary barrier systems, development of an integrated quality assurance scheme and a preliminary reliability-based design methodology for bioengineered slopes. Findings from this project will provide new insights into the behaviour of bioengineered slopes and landfills in Hong Kong. A novel, specific reliability-based preliminary design guideline will be developed for the design, construction, management and restoration of bioengineered live cover systems on both man-made fill slopes and landfill capillary barriers. The guideline will set out performance standards, technical information, procedural mechanisms (integrated design, construction and operational phases), and will provide necessary supporting data.



Figure 88. Advisory committee meetings

## Research highlights

### Hong Kong University of Science and Technology (HKUST) Geotechnical Group (Con't)

#### Task A: Field Monitoring and Site Characterization of Man-made Slopes and Landfills

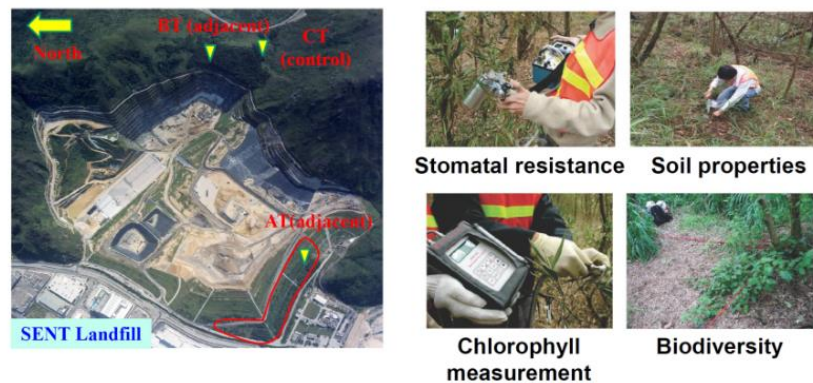


Figure 89. Ecological monitoring of the restored south east new territories (SENT) landfill in Hong Kong (2000 - on going) (Chen *et al.* 2016; Wong *et al.* 2016)

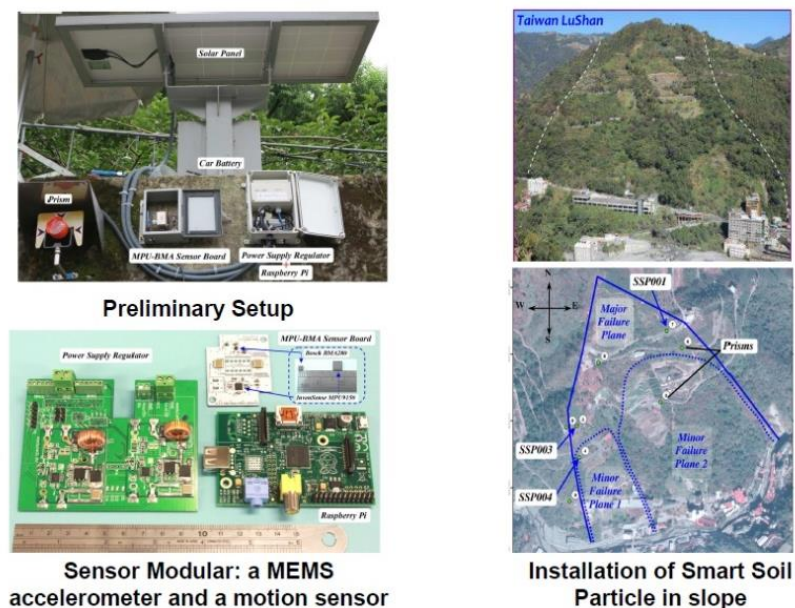


Figure 90. Developed Smart Soil Particle: economical but accurate sensor to monitor slope and landfill cover movements (Ooi *et al.* 2015)



Figure 91. Shenzhen Xiaping landfill monitoring site



## Research highlights

### Hong Kong University of Science and Technology (HKUST) Geotechnical Group (Con't)

#### Task B & C: Pole-soil mechanical and water-gas flow interactions; Failure Mechanism and Stability

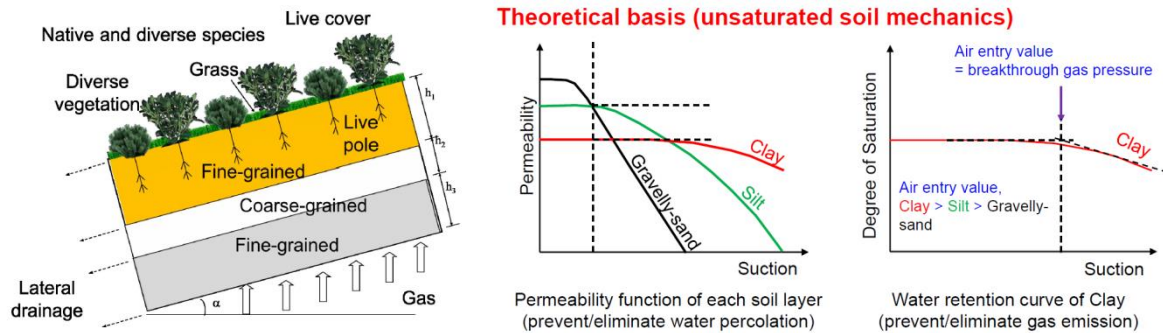


Figure 92. Newly three-layer landfill cover system [Ng *et al.* U.S. Patent No. 9,101,968 B2 (2015)]

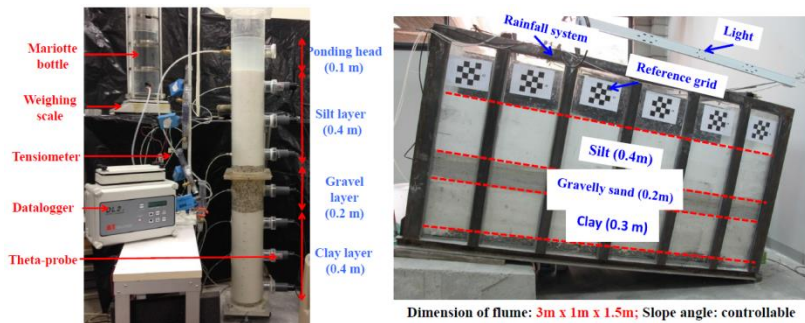


Figure 93. Overview of a typical test for the three-layer landfill cover system using one-dimensional soil column and two-dimensional flume (Ng *et al.* 2015a; Ng *et al.* 2015b; Ng *et al.* 2016a)

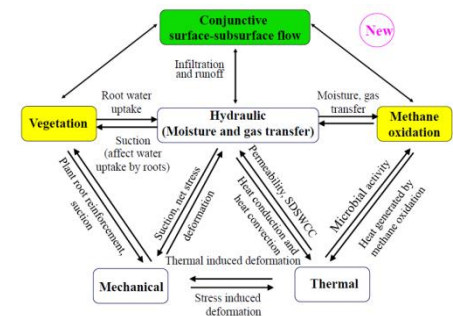


Figure 94. A new fully coupled model for water-gas-heat-reactive transport with methane oxidation in landfill covers (Ng *et al.* 2015c)

#### Effect of vegetation on man-made fill slopes and landfill covers

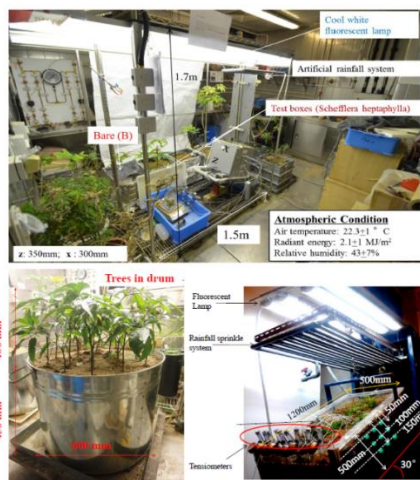
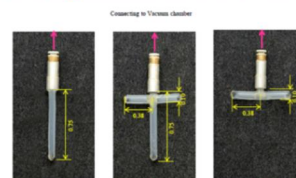


Figure 95. Overview of laboratory tests (Ng *et al.* 2016b; Ni *et al.* 2017)

#### a. Using artificial material for different root geometry



#### b. Using natural stem cutting

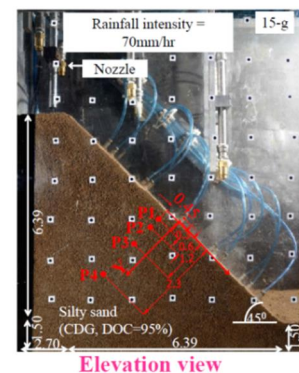
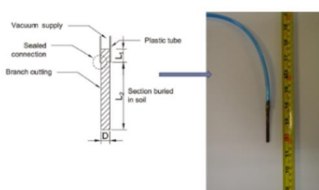


Figure 96. Two new developed techniques to simulate plant transpiration induced suction in centrifuge (Ng & Yu 2014; Ng *et al.* 2014)

## Research highlights

### Hong Kong University of Science and Technology (HKUST) Geotechnical Group (Con't)

#### Task D: Integrated Quality Assurance and Reliability-based Design

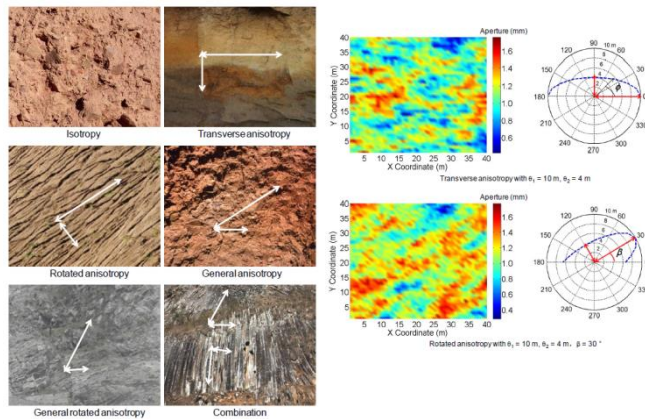
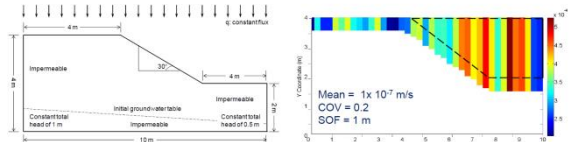


Figure 97. Anisotropic random fields for soil (Zhu & Zhang 2013)

#### Modelling spatial variations of evapotranspiration of grass



#### Computed factor of safety (FoS) of vegetated slope under rainfall

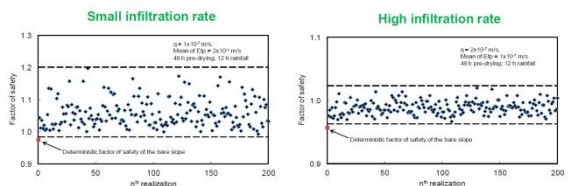


Figure 98. Slope stability analysis considering uncertainty of vegetation (Zhu & Zhang 2015)

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## Research highlights

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## Research highlights

### Hong Kong University of Science and Technology (HKUST) Geotechnical Group (Con't)

#### 5. Activities and Events

##### 5.1. Social

As a group we believe life as a university student goes beyond research. We strive to keep our students engaged in activities that will foster new friendships and maintain a healthy lifestyle, ultimately leading to a more well-rounded university experience. Students are encouraged to join or even organize their own activities. Activities include annual BBQ events, various sports activities etc.



Figure 99. Students celebrating after winning a soccer match



Figure 100. Students enjoying a game of basketball



Figure 101. Students enjoying a relaxing BBQ evening

##### 5.2. Events

To promote academic exchange and enhance the groups' international exposure, our group hosts conferences, seminars, symposia, and workshops etc. This will not only lead to scientific advancement, but attracts the best scholars from around the world with whom our students can have meaningful engagement. Recent events hosted by our group include the 4<sup>th</sup> International Symposium on Geotechnical Safety and Risk (ISGSR 2013), 4-6 December 2013; the 1<sup>st</sup> International Conference on Geo-Energy and Geo-Environment (GEGE 2015), 4-5 December 2015; and the 1<sup>st</sup> International Symposium on Soil Dynamics and Geotechnical Sustainability (ISSDGS 2016), 7-9 August 2016. One of the future events includes the 7<sup>th</sup> International Conference on Unsaturated Soils (UNSAT 2018), 3-5 August 2018. For more information on this conference please consult the website at: <http://www.unsat2018.org/>

## Research highlights

### Hong Kong University of Science and Technology (HKUST) Geotechnical Group (Con't)

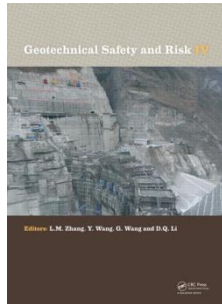


Figure 102. Proceedings of Geotechnical Safety and Risk IV (Zhang *et al.* 2013)



Figure 103. ISGSR 2013 opening address

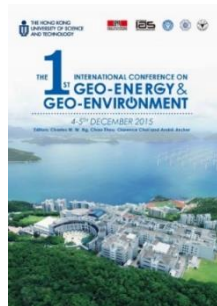


Figure 104. Proceedings of GEGE 2015 (Ng *et al.* 2015)



Figure 105. GEGE 2015 participants

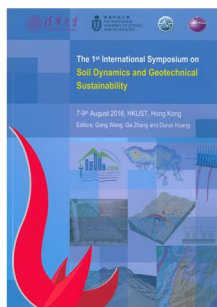


Figure 106. Proceedings of ISSDGS 2016 (Wang *et al.* 2016)

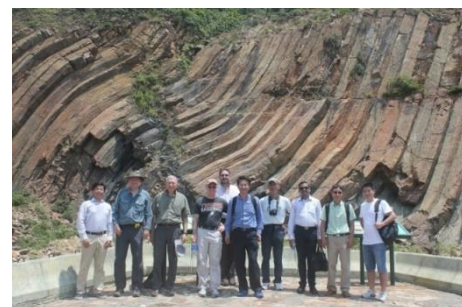


Figure 107. ISSDGS 2016 participants on a field trip

#### 5.2.1. References

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## Project highlight

### Pilot the way to Hong Kong's urban underground space development

Developing underground spaces is not a fresh idea in Hong Kong. Existing underground spaces were normally constructed on a project basis without holistic planning. There has been long discussion about how we could apply this concept wisely to address the problems encountered in the built-up areas. It demands efforts to plan holistically and generate solutions that suit the needs of individual areas and the interests of the society.

The Hong Kong SAR Government's pilot study on underground space development for four selected urban areas, viz. Tsim Sha Tsui West, Causeway Bay, Happy Valley and Wan Chai/Admiralty, is now going through this process. Our vision is to create a well-connected network of multifunction underground spaces that can enhance connectivity and address space shortage issues in one go. There are numerous examples across the globe showing successful use of interconnected underground space to alleviate at-grade congestion. The sub-surface usage can go beyond simply retail and can extend to a broad range of uses, including community and recreational facilities. These successful cases provide us with a new dimension of thoughts in exploring underground space solutions so as to bring significant public gains to our city.

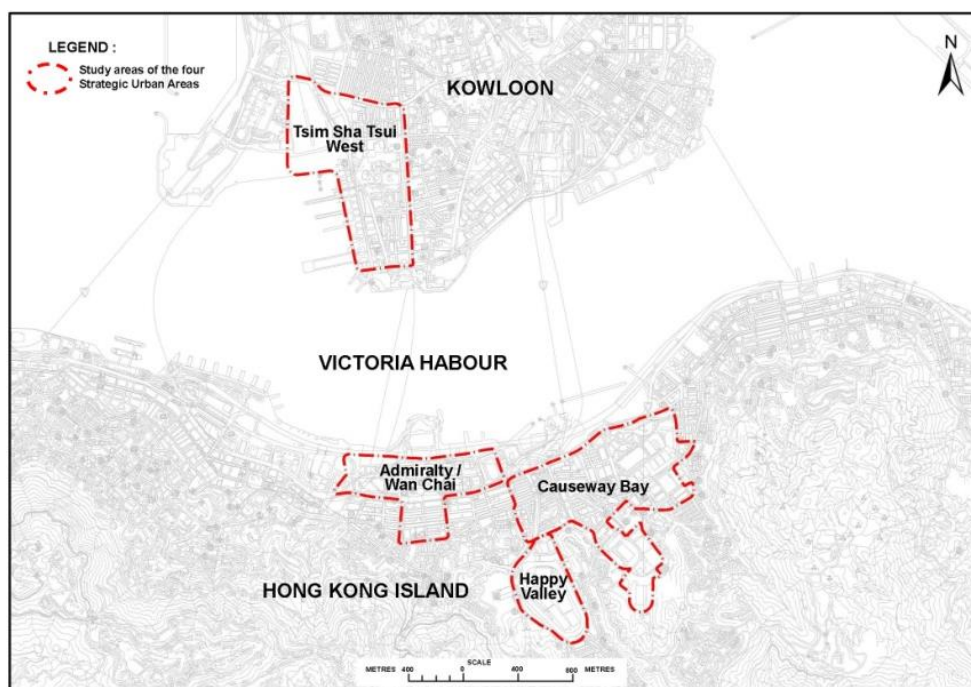


Figure 1. Four study areas under the Pilot Study on Underground Space Development



Figure 2. Notable examples of underground space developments



## Project highlight

### Pilot the way to Hong Kong's urban underground space development (Con't)

The four study areas are located within the dense urban core of Hong Kong, which are known to have congested pedestrian environment and limited land resources for further development, including lack of community facilities to meet the district needs. The study aims to explore the potential of using underground space to address the problems in these areas, formulate an underground master plan for each area and draw up suitable underground space development proposals for possible future implementation.

Commenced in June 2015, the study is now in its mid-way, with preliminary planning concepts formulated for each area. Taking Tsim Sha Tsui West as an example, the area is densely developed with busy streets. The study recommends utilising the space underneath the Kowloon Park to create a regional multi-directional underground pedestrian network so as to improve the connectivity between the Tsim Sha Tsui hinterland and the new development areas including the West Kowloon Cultural District. The all-weather network can also provide new space to accommodate various kinds of facilities, thus making the underground pedestrian environment more vibrant and appealing.



Figure 3. Preliminary planning concepts of underground space development in Tsim Sha Tsui West

The study comprises a two-stage public engagement programme. The first stage public engagement completed early this year focused on the opportunities, constraints and key considerations, including geotechnical challenges of developing underground space in these areas. The exercise has stimulated discussions among the public about possible uses of underground space and the worthiness of developing underground space given concerns with various short- and long-term impacts. The preliminary planning concepts developed for the four study areas are initial thoughts at this stage. Conceptual schemes and underground master plans will be developed taking due consideration of the views received. Technical assessments covering various aspects, including geotechnical, fire safety, traffic and impact on the surrounding environment will be carried out. More details will be presented in the next stage of public engagement.

Further information of the study can be found in the project website and facebook page ([www.urbanunderground.gov.hk](http://www.urbanunderground.gov.hk) and [www.facebook.com/urbanundergroundhk](https://www.facebook.com/urbanundergroundhk), respectively).

## Project highlight

### Pilot the way to Hong Kong's urban underground space development (Con't)

#### About the authors:

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Mr Y K Ho is a Chief Geotechnical Engineer in the Geotechnical Engineering Office of the Civil Engineering and Development Department. He oversees the strategic studies on both rock cavern and underground space development. His division is also responsible for providing technical support and advice to other government departments involving rock cavern and underground space development.

Mr Ho obtained his MSc degree from Imperial College, London and BEng degree from the University of Hong Kong. He has over 20 years' experience in civil and geotechnical engineering. He currently serves as a member of the Advisory Board of the International Tunnelling and Underground Space Association Committee on Underground Space (ITACUS) and a member of ISSMGE TC204 on Underground Construction.



##### Johnny Cheuk

Dr Johnny Cheuk obtained his PhD from the Cambridge University. He is currently Director of Operations and Executive Director for Geotechnical in AECOM in Hong Kong, and handles a wide spectrum of geotechnical projects, including slopes, tunnels, deep excavations and offshore engineering for public and private clients. He specializes in numerical and physical modelling of soil-structure interaction.

Johnny has won numerous local and international awards, including the Tan Swan Beng Best Paper Award of the Southeast Asia Geotechnical Society, the Fugro Prize, R.M. Quigley Honourable Mention of the Canadian Geotechnical Society, the British Geotechnical Association (BGA) Medal and the HKIE Young Engineer of the Year Award. He is currently Secretary General of the Hong Kong Geotechnical Society, and is an Adjunct Associate Professor at the University of Hong Kong. Johnny is also a member of ISSMGE TC103 and TC104.

