Second JTC1 Workshop

3 to 5 December 2018 | Hong Kong

Triggering and Propagation of Rapid Flow-like Landslides

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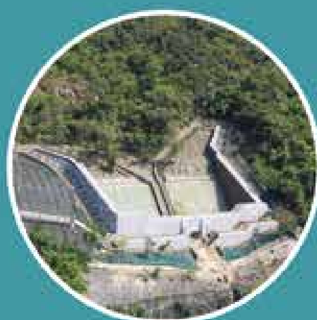

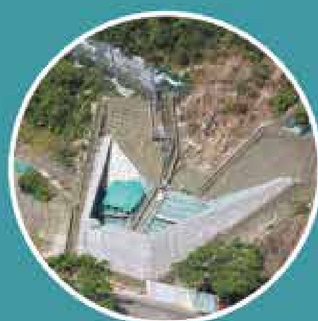

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Second JTC 1 Workshop 2018

Triggering and Propagation of Rapid Flow-like Landslides

3-5 December 2018
Hong Kong

Jointly organised by:

- Joint Technical Committee on Natural Slopes and Landslides (JTC1) of Federation of International Geo-engineering Societies (FedIGS), the alliance of the learned societies ISSMGE, ISRM, IAEG and IGS
- The Hong Kong Geotechnical Society
- The Geotechnical Division of the Hong Kong Institution of Engineers
- The Hong Kong University of Science and Technology

2nd JTC1 workshop website:

http://www.hkges.org/JTC1_2nd

Extended abstracts:

http://www.hkges.org/JTC1_2nd/paper.html

Contents

Cover design by Arup

Organisation

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Special Acknowledgements

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The Hong Kong Polytechnic University - Department of Civil and Environmental Engineering

The University of Hong Kong - Department of Civil Engineering

The University of Hong Kong - Department of Earth Sciences

The Institute of Materials, Minerals and Mining Hong Kong Branch

Welcome Message

On behalf of the International Society for Soil Mechanics and Geotechnical Engineering (ISSMGE), I am pleased to welcome you to the 2nd JTC1 workshop.

With the impact of climate change on landslides and the need for sustainable development in mountainous regions around the world, I am excited to see the alliance among the learned societies, ISSMGE, the International Society for Rock Mechanics and Rock Engineering (ISRM), International Geosynthetics Society (IGS) and the International Association for Engineering Geology (IAEG), dedicated to tackling the challenges pertaining to “Triggering and Propagation of Rapid Flow-like Landslides.”

Prof. Charles Ng

A glance through the list of presentations and events planned over the next few days reveals a rich diversity of researchers from all around the world sharing their experience in risk management, field monitoring, physical modelling, numerical modelling, and of notable case histories. High level workshops, such as JTC1, provide a valuable opportunity for scientists, engineers, and decision makers to share knowledge and to establish collaborations.

I am sure that you will have fruitful and rewarding exchanges over the next few days. I wish you every success and I am excited to learn about the outcome of this workshop.

Prof. Charles Ng
President
International Society of Soil Mechanics and Geotechnical Engineering

Welcome Message

Prof. Eda F. de Quadros

On behalf of the International Society for Rock Mechanics and Rock Engineering (ISRM), I am glad to welcome the Second JTC1 Workshop on Triggering and Propagation of Rapid Flow-Like Landslides, organised by the Joint Technical Committee of FedIGS, JTC1 together with the Hong Kong University of Science and Technology, in the pleasant of Hong Kong, China, from 3 to 5 December, 2018.

The JTC1 (Natural Slopes and Landslides Committee) is one of the four technical committees of the Federation of the International Geoengineering Societies (FedIGS) which is a collaborative forum that gathers the four geotechnical societies ISSMGE, IAEG, IGS and ISRM, having the main objective to improve the relationship and exchanging of information among the international geotechnical societies.

The Chairman of the JTC1 is Prof. Luciano Picarelli from Italy, who has proposed and accompanied the success of the committee for many years. The main objective of the JTC1 is to ensure the exchange of information in research and development among international teams working on topics linked to professional solutions and understanding of the phenomenology involved with landslides aiming to prevent their occurrence and proposing actions of mitigation.

The present Workshop will discuss some important themes linked to landslides, like triggering, risk management, propagation, mitigation and the influence of climate changes on the landslides occurrence. It is with great satisfaction that I wish to the organisers and participants a great success in the Workshop.

Prof. Eda F. de Quadros
President
International Society for Rock Mechanics and Rock Engineering

Welcome Message

Prof. Luciano Picarelli

Welcome to the JTC1 Workshop on "Triggering and Propagation of Rapid Flow-Like Landslides".

This is the second international workshop organised by the Joint Technical Committee no 1 (JTC1) "Natural Slopes and Landslides" of the Federation of the International Geo-engineering Societies (FedIGS). Its aim is to invite strict international cooperation on hot and advanced topics, involving people which work in the wide domain of the geo-sciences to contribute their expertise in the solution of complex problems. Another important goal of the event is promoting a more stringent scientific involvement of young researchers in advanced research topics, thus making the most of the enthusiasm and freshness of their minds while offering them an opportunity to put in place new ideas.

This workshop, which follows the analogous event (the 1st JTC1 WS) held in Barcelona in the spring of 2017 on "Advances in Landslide Understanding", will include the 2nd Hutchinson Lecture, which is another initiative of the JTC1 aimed at awarding emerging young scholars, and a Hungr Oration in memory of our dear colleague Oldrich, who was an outstanding and dearly remembered member of the committee. Also, the workshop will include several keynote lectures and invited lectures from emerging talents and an intriguing benchmarking exercise on landslide propagation.

Don't worry, the committee is already planning the 3rd JTC1 WS, which should take place midway between the 13th (Cartagena, 2020) and the 14th International Symposium on Landslides (2024)!

Prof. Luciano Picarelli
Chairman
JTC1 "Natural Slopes and Landslides", FedIGS

Welcome Message

I would like to extend a warm welcome to all participants of the Second Joint Technical Committee on Natural Slopes and Landslides (JTC1) Workshop on Triggering and Propagation of Rapid Flow-like Landslides.

As a signature event, this Workshop has brought together internationally renowned experts, top-notch professionals, eminent academics and captains of industry to share their experience, insight and wisdom. The Organising Committee has designed a rich technical programme. Apart from the keynote addresses, the programme also features the Second Hutchinson Lecture, the Hungr Oration to commemorate the contributions of the late Professor Oldrich Hungr, Special Lectures to be delivered by young, emerging stars, and a dedicated session on Benchmarking Exercise for landslide runout analysis.

Prof. Ken Ho

The organisation of such an international showpiece event is no easy task, and the workshop would not have been successful without the dedication and commitment by all involved. I would like to thank the Chairman and members of JTC1, President of ISSMGE and the International Advisory Panel for their solid support. I would also like to extend my sincere gratitude to all members of the Organising Committee and the various subcommittees, Hong Kong Geotechnical Society, HKIE Geotechnical Division and Hong Kong University of Science and Technology.

I wish to convey my heartfelt appreciation to Dave Chan, Suzanne Lacasse, Serge Leroueil, Brian McArdell, Farrokh Nadim, Dave Petley and Chan-Young Yune for their assistance in chairing the various sessions. Last but not least, special thanks are due to all the distinguished speakers as well as sponsors.

I wish you all a fruitful and memorable workshop.

Prof. Ken Ho
Chairman
Organising Committee of Second JTC1 Workshop

Scientific Programme – Day 1

Opening				
08:30-09:00	**Registration**			
09:00-09:15	Opening Speech by Guests of Honour		**Charles NG** President of International Society for Soil Mechanics and Geotechnical Engineering **Norikazu SHIMIZU** Vice-President of International Society for Rock Mechanics and Rock Engineering **Luciano PICARELLI** Chairman of JTC1	
09:15-09:25	Presentation of Certificates of Appreciation to Sponsors			
09:25-09:30	Photo Session			
Morning Session (Moderator: Suzanne LACASSE)				
09:30-10:00	Keynote Address		**Alexander PUZRIN**	
10:00-10:30	Hungr Oration		**Scott MCDOUGALL**	
10:30-10:55	**Coffee Break**			
10:55-11:15	Theme Lecture		**Jean-Sebastien L'HEUREUX**	
11:15-11:35	Theme Lecture		**Ching HUNG**	
11:35-11:55	Theme Lecture		**Clarence CHOI**	
11:55-12:25	Panel Discussion			
12:25-12:30	Photo Session			
12:30-14:00	**Lunch**			
Afternoon Session (Moderator: Chan-Young YUNE)				
14:00-14:30	Keynote Address		**Manuel PASTOR**	
14:30-14:50	Theme Lecture		**Sabatino CUOMO**	
14:50-15:10	Theme Lecture		**Anja DUFRESNE**	
15:10-15:30	**Coffee Break**			
	Plenary Session 1: Landslide analysis and numerical methods Venue: IAS Lecture Theatre Moderator: **Chan-Young YUNE**		*Plenary Session 2: Landslide mechanisms, experiments and monitoring* Venue: IAS Meeting Room No. 1038 Moderator: **Dave CHAN**	
15:30-15:45	Oral Presentation	**Jordan AARON**	Oral Presentation	**Daoyuan TAN**
15:45-16:00	Oral Presentation	**Yifei CUI**	Oral Presentation	**Harris LAM & Anthony WONG**
16:00-16:15	Oral Presentation	**Shuang ZHENG**	Oral Presentation	**Ruiwang YU**
16:15-16:30	Oral Presentation	**Fiona KWOK**	Oral Presentation	**Sangseom JEONG**
16:30-17:00	Panel Discussion		Panel Discussion	
17:00-17:05	Photo Session		Photo Session	

Scientific Programme – Day 2

Opening		
08:30-09:00	**Registration**	
Benchmarking Exercise on Landslide Runout Analysis (Moderator: **Dave PETLEY**)		
09:00-09:25	Overview by Review Sub-committee	**Kenichi SOGA**
09:25-09:40	Oral presentation	**Marc PERUZZETTO**
09:40-09:55	Oral presentation	**Jidong ZHAO**
09:55-10:10	Oral presentation	**Andrew MITCHELL**
10:10-10:25	Oral presentation	**Arthur CHEUNG**
10:25-10:40	Oral presentation	**Raymond LAW**
10:40-10:55	**Coffee Break**	
10:55-11:10	Oral presentation	**Manuel PASTOR**
11:10-11:25	Oral presentation	**Marina PIRULLI**
11:25-11:40	Oral presentation	**Kahlil Fredrick CUI & Yunxu XIE**
11:40-11:55	Oral presentation	**Moonhyun HONG**
11:55-12:25	Panel Discussion	
12:25-12:30	Photo Session	
12:30-13:30	**Lunch**	
	JTC1 Lunch Meeting (Venue: IAS Meeting Room No. 5007)	
Afternoon – Technical visits		
13:30-17:00	Option 1: HKUST centrifuge facility	**Clarence CHOI**
	Option 2: Debris-resisting barriers at Yu Tung Road	**Raymond KOO** **David MAK**
	Option 3: Headquarters of Geotechnical Engineering Office (GEO)	**Julian KWAN**
18:30-21:00	**Gala Dinner**	

Scientific Programme – Day 3

Opening				
08:30-09:00	**Registration**			
Morning Session (Moderator: Serge LEROUEIL)				
09:00-09:30	Keynote Address		**John WHITTALL**	
09:30-09:50	Theme Lecture		**Vidya Bhushan MAJI**	
09:50-10:10	Theme Lecture		**Shintaro NOHARA**	
10:10-10:30	Theme Lecture		**Dominique TURMEL**	
10:30-10:50	**Coffee Break**			
Plenary Session 3: Landslide propagation and mitigation				
10:50-11:05	Oral Presentation		**Alexander STROM**	
11:05-11:20	Oral Presentation		**Dongri SONG**	
11:20-11:35	Oral Presentation		**Hannes SALZMANN**	
11:35-12:05	Panel Discussion			
12:05-12:10	Photo Session			
12:10-14:00	**Lunch**			
Afternoon Session (Moderator: Brian MCARDELL)				
14:00-14:30	Keynote Address		**Ken HO**	
14:30-15:10	Hutchinson Lecture		**Núria PINYOL**	
15:10-15:30	**Coffee Break**			
	Plenary Session 4: Numerical analysis and landslide risk mitigation Venue: IAS Lecture Theatre Moderator: **Brian MCARDELL**		*Plenary Session 5: Experiments, case studies and monitoring* Venue: IAS Meeting Room No. 1038 Moderator: **Farrokh NADIM**	
15:30-15:45	Oral Presentation	**Hu ZHAO**	Oral Presentation	**Jon CAREY**
15:45-16:00	Oral Presentation	**Jelka KRUŠIĆ**	Oral Presentation	**Yu LEI**
16:00-16:15	Oral Presentation	**Alex STROUTH**	Oral Presentation	**Yusrin Faiz WAHAB**
16:15-16:30	Oral Presentation	**Alessandro LEONARDI**	Oral Presentation	**Rajinder BHASIN**
16:30-17:00	Panel Discussion		Panel Discussion	
17:00-17:05	Photo Session		Photo Session	
17:05-17:15	**Closing Remarks** **Ken HO** Chairman of Organising Committee **Luciano PICARELLI** Chairman of JTC1			

Keynote Address

Effects of sedimentation and shearing on the triggering of flow-like submarine landslides

Abstract

The initial release volume and geometry of the unstable sediments are key parameters for debris flow simulations. Conventionally, these parameters are predicted using limiting equilibrium methods, where the unstable portions of the slope fail simultaneously. This assumption does not always reflect the real failure mechanism, leading to potential inaccuracies in the predicted release volumes of the unstable soil mass and its subsequent runout behaviour. This work describes recent developments that allow for a better understanding of the mechanisms of landslide conditioning and triggering, providing improved inputs for debris flow analyses. These mechanisms include shear band propagation, slip surface formation due to rapid sedimentation and effects of shearing on runout energy and sediment fluidization. The presented work describes these mechanisms and attempts to quantify their effects on the subsequent landslide runout behaviour, by using a combined three-step procedure, developed within the ABAQUS computing environment.

Prof. Alexander M. Puzrin

Brief Biography

Alexander M. Puzrin is Professor and Chair of Geotechnical Engineering at the ETH Zurich, Switzerland. He is engaged in the constitutive modelling of geomaterials and the analysis of progressive and catastrophic failure in soils, with applications to onshore and offshore slope stability problems. His other interests are in applications of novel sensor technologies to geotechnical monitoring and in assessment and mitigation of geotechnical eco-hazards. His research papers received multiple awards from the UK Institution of Civil Engineers (ICE). Professor Puzrin has been involved as an expert and consultant in large-scale onshore and offshore geotechnical projects in the UK, the US, Switzerland, Mexico, Azerbaijan, Russia, and Israel. He is a co-founder of the ETH Zurich spin-off company Marmota Engineering AG providing fiber optics geotechnical monitoring services to industry. He served as the Editor of Géotechnique in 2012–2015.

Keynote Address

Modelling of propagation of fast landslides

Abstract

The talk deals with modelling of propagation of fast, shallow landslides with large velocities of propagation and the waves they can induce in lakes, fjords and other water bodies First of all, I will describe a set of hierarchically structured mathematical models describing the coupling between soil skeleton and pore fluids, obtaining from 3D models depth integrated models. The more complex case is that of debris flows, where large relative velocities between solid and pore fluids exist.

Rheological behaviour of fluidized soils plays a paramount role in propagation of fast landslides. I will show how 3D viscoplastic constitutive models and some rheological models provide similar results. Models for cohesive, frictional and viscous materials will be presented. In the case of granular materials, models depending on the Inertia number provide the possibility of taking phenomena like crushing into account, as particles size affects the basal friction.

Prof. Manuel Pastor

The numerical technique which will be used to discretize the mathematical model is SPH. Here, it is possible to use two sets of nodes to describe water and solid particles movement. This technique will be applied to waves generated by landslides in water bodies and to debris flows. Some numerical tools describing more complex problems as water inflow from lateral weirs will be described. The quality of the models will be assessed by real fast landslide cases, including rock avalanches, mudflows, flowslides and debris flows.

Brief Biography

Professor Manuel Pastor is Professor of Applied Mathematics and Computer Science Department, ETS Caminos, Universidad Politécnica de Madrid. He is a member of the Royal Academy of Sciences (Sevilla) since 2006, Visiting Scholar at Universities of Swansea, UK, Grenoble and Imperial College of London and Honorary Professor at Hohai University (Nanjing, China). His research interests include soil dynamics (laboratory testing and constitutive modelling, dynamic behaviour of road materials, finite element and SPH modelling on geotechnical engineering and harbour engineering and hydraulics engineering. Professor Pastor has been active in various international projects and network, such as the Project Safeland, and Network ALERT Geomaterials, where he served on the Board of Directors and was the former President from 2011-2017. He is also a member of the Board of Advisors of LARAM courses, Editorial Panel Member for journals including Geotechnique, Computer Methods in Engineering Sciences, European Journal of Environmental and Civil Engineering, International Journal for Numerical and Analytical Methods in Geomechanics, and Rock Mechanics and Rocks Engineering.

Keynote Address

Mines: a landslide laboratory

Abstract

Studying landslides in a mining context provides the advantage of known geometry, monitored climatic conditions, and near-continuous deformation monitoring. Stripped of exogenic influences like topographic variability and liquefiable substrate, observations from pit slope failures provide useful evaluation of the influences on runout distance. Similarly, mine waste dump failures provide an opportunity to assess the influence of travel path conditions on runout of a loose fill with known construction history. Both open pit and waste dump landslides have separate mobility behaviors based on material characteristics. The properties of the rock mass are the key predictors of open pit runout behavior, and high mobility cases occur with rock mass structure that is able to contract in shear. The key predictors of high mobility waste dump failures are the potential for material strength loss or rapidly loading liquefiable substrate. Identifying the high mobility cases is imperative to maintaining the safety of workers and downstream communities. Successful and misguided applications of a risk context are presented to demonstrate how runout affects decision-making in a mining context.

Mr. John Whittall

Brief Biography

John Whittall is a geological engineer with specialization in landslide runout and risk reduction at operating mines. His interest in geology began in an elective course on natural hazards while pursuing an architecture degree. He quickly transferred to geological engineering at Queen's University with a focus on rock mechanics. Post-undergrad, John began his consulting experience with BGC Engineering Inc. investigating and designing open pit mines and waste dumps and providing operational support. In the course of this work, a large, slowly-deforming landslide situated above an open pit lead a client to ask, "what happens if this pit slope accelerates and runs into the open pit?" Unsatisfied with the tools available, John returned to school at the University of British Columbia and developed pit slope failure runout tools and a risk framework for working below a deforming slope. His current consulting assignments include a 50/50 mix of mining and municipal landslide hazard and risk projects. Key interests include geology influences on deformation and runout behaviour, coaching mine staff on harmonizing geotechnical safety and productivity, and helping clients make informed, transparent mitigation decisions.

Keynote Address

Advances in risk mitigation practice for natural terrain landslides in Hong Kong

Abstract

Dense urban development on a hilly terrain, coupled with intense seasonal rainfall and heterogenous weathered profiles, gives rise to acute debris flow problems in Hong Kong. The Geotechnical Engineering Office (GEO) has launched a holistic R&D programme and collaborated with various tertiary institutes and professional bodies to support the development of a comprehensive technical framework for managing landslide risk and designing debris flow mitigation measures with more scientific rigour. The scope of the technical development work includes compilation of landslide inventories, field studies of debris flows, development and calibration of tools for landslide mobility modelling, back analysis of notable debris flows, physical and numerical modelling of the interaction of debris flow and mitigation measures, formulation of a technical framework for evaluating debris flow hazards, and development of pragmatic mitigation strategies and design methodologies for debris flow countermeasures.

The work, which spans over the last two decades, has advanced the technical understanding of debris flow hazards and transformed the natural terrain landslide risk management practice in Hong Kong. New analytical tools and improved design methodologies are being applied in routine geotechnical engineering practice by local practitioners. One of the key elements of the ongoing technical development work is the use of large-scale physical models to verify the actual behaviour of debris flow mitigation measures, and to test and calibrate the various predictive tools with a view to optimising or further rationalising the design approaches. This paper presents the progressive development of the natural terrain risk management practice in Hong Kong, together with the notable advances made as a result of technical development work.

Prof. Ken Ho

Brief Biography

Professor Ken Ho obtained his undergraduate and postgraduate degrees at Imperial College London, specialising in earthquake engineering. He is the Deputy Head of Geotechnical Engineering Office of Hong Kong SAR Government, which is an internationally renowned Centre of Excellence in landslide risk management. Ken is a seasoned professional and an Adjunct Professor of University of Hong Kong, and has made contributions to advance both theory and practice. He has published over 130 technical papers, including journal papers, keynote papers and state-of-the-art papers at various international conferences. He is a core member of JTC1 of ISSMGE, IAEG, ISRM and IGS, and serves on the editorial boards of the journals Landslides and Georisk. He has been appointed as a Justice of the Peace in 2012 and is the currently Chairman of the Institution of Civil Engineers Hong Kong Association.

Hungr Oration

A practical approach to landslide science: the legacy of Professor Oldrich Hungr

Abstract

The landslide and broader geotechnical communities lost a key voice with the sudden passing of Oldrich Hungr in August 2017. Professor Hungr made several major contributions to landslide science and practice over his 40 year career as a researcher and consulting engineer, including the development of widely-adopted methods for landslide stability and runout analysis. His work was characterized by an overarching theme of pragmatism. He approached the complex subject of landslides from a geo-practitioner's viewpoint, advocating for relatively simple methods that, when combined with factual observations and professional judgment, could still provide powerful insight and a basis for sound decision making. This talk discusses this theme and describes its extension to more recent and ongoing research that Professor Hungr inspired and helped to develop. This work includes the adaptation of methods from optimization theory and Bayesian statistics to facilitate more repeatable calibration of numerical runout models, and the application of emerging remote and field data collection methods to improve the case study data available for model calibration. In line with Professor Hungr's vision, in the hands of skilled practitioners, these methods help improve our ability to manage the risks associated with rapid, flow-like landslides.

Prof. Scott McDougall

Brief Biography

Professor Scott McDougall is an Assistant Professor of Geological Engineering in the Department of Earth, Ocean and Atmospheric Sciences at the University of British Columbia (UBC) in Vancouver, Canada. He completed a B.A.Sc. in Civil Engineering at the University of Toronto in 1998 and a Ph.D. in Geological Engineering at UBC in 2006. Before joining the faculty at UBC full-time in 2016, he worked for 10 years as a consultant with BGC Engineering in Vancouver, where he was engaged in a wide variety of projects in the mining, energy, transportation and municipal development sectors. He specializes in the development of tools and techniques for the assessment of geohazards, including landslides, landslide-generated waves, shoreline erosion and dam breaches.

Hutchinson Lecture

Physics of landslides

Abstract

Friction plays a key role in landslide creeping, failure and post failure behaviour. With the aim of predicting not only the onset of the failure, but also the maximum landslide extension and velocity, necessary to identify vulnerable area for risk assessment, accurate estimation of laws describing properly the friction in wide range of strains is required. Experimental evidence shows friction hardening and weakening due to both intrinsic behaviour of granular soils and coupling effects. In particular, the lecture presents an insight on the following phenomena affecting the dynamic friction: friction strengthening due to rate effects, frictional heating-induced weakening, weakening due to loss of suction and static and dynamic mechanical pressurization (liquefaction). These phenomena will be modelled within the framework of the material point method. Academic examples as well as real cases will be simulated to highlight some features.

With the aim of validating numerical results by means of comparing them with experiments, digital image correlation is widely used because it provides massive and non-invasive information for any range of displacement. The lecture also focuses on novel methodologies to measure and interpret variables of interest of experiments (displacement, velocity, strains and degree of saturation) based on image processing.

Prof. Núria Pinyol

Brief Biography

Núria Pinyol, civil engineer (Barcelona, 2004), got her PhD in Geotechnical Engineering at Universitat Politècnica de Catalunya (UPC, Spain) in 2010. At present, she is Associate research professor in CIMNE and Lecturer in Civil and Environmental Engineering School of UPC.

Main research contributions addressed on the behaviour of unsaturated soils and thermo-hydro-mechanical coupling on landslides. She developed, for the first time, a coupled formulation into a general numerical tool for the analysis of landslides including thermal dissipation at shear band level to explain the sudden and catastrophic acceleration. Her research work was awarded with the Crampton Prize (Institution of Civil Engineers (ICE), UK, 2008), Best Paper Award on Landslides (International Consortium of Landslides, 2010), the Geotechnical Research Medal (ICE, 2014), the Telford Gold Medal (ICE, 2016) and the Baker Medal (ICE, 2017). She is author of two books on "Geomechanics of Failures" addressed to civil and geotechnical engineers, which are the documentation of reference in Geotechnical courses around the world. She worked as a geotechnical adviser on several geotechnical projects, in which, in some cases, she applied the last contributions of the knowledge frontier.

Theme Lecture

Smart multi-level flexible net barrier system

Abstract

Rainfall events are intensifying due to climate change, increasing the risk posed by debris flows to human developments near natural slopes across the world. To ensure developments sustainably mitigate risk from these debris flows, engineers will look for structural countermeasures that: (i) blend in well with the natural environment, (ii) are self-cleaning, thus minimising maintenance; and (iii) are smart, so that they can relay their performance to engineers. This seminar will present the development of a new paradigm of debris flow mitigation that adopts smart multi-level net barriers capable of detecting impact events. To develop this new mitigation system, physical model tests were carried out to: (i) study the fundamental impact dynamics of wide range of flow types; (ii) investigate how to minimise particle trapping within net barriers to enable feasible self-cleaning designs; and (iii) evaluate the performance of smart impact switches on barriers to detect impact events. Physical tests were back-analysed using the discrete element method. Results were then used to develop a new 3D framework to unify and characterise the impact behaviour of a wide range of flow types. New analytical approaches were also developed to predict the impact force on net barriers and to identify the flow regimes where self-cleaning is possible. Finally, a preliminary evaluation of a smart impact switch was carried out.

Dr. Clarence Choi

Brief Biography

Dr. Clarence Choi is a Research Assistant Professor in the Department of Civil and Environmental Engineering at The Hong Kong University of Science and Technology and a Junior Fellow of the Institute for Advanced Study. Dr Choi received the 2017 Telford Premium Prize from the Institution of Civil Engineers of the UK and the 2017 R.M. Quigley award from the Canadian Geotechnical Society. He is currently the chair of the international committee for debris flow and steep creek hazards mitigation of the Association of Geohazard Professionals and is a chair-nominated member of the technical committee on slope stability of the International Society for Soil Mechanics and Geotechnical Engineering.

Theme Lecture

SPH propagation modelling of flow-like landslides along engineered slopes in pyroclastic soils

Abstract

The paper deals with different examples of slopes engineered with the purpose of reducing the negative impacts of flow-like landslides. The geoenvironmental context is that of the pyroclastic soils originated by the eruptions of the Vesuvius volcano which are present in a 3,000 km² wide area in the Campania region (Italy). Some relevant case studies are analyzed with reference to either channelized debris flows or unchannelized debris avalanches. A series of different control works are considered as well along the slopes, including: i) the construction of rigid baffles, or ii) anti-erosion installations. Alternatively, the attention is focused at the piedmont area, considering: i) draining racks, or ii) rigid barriers transversal to the flow direction. Aware of the limitations which still exist in the proposed numerical modelling, the overall features of the simulated flows are discussed trying to extrapolate somehow general considerations about the beneficial effects and drawbacks of each type of control work in relation to the type of flow.

Prof. Sabatino Cuomo

Brief Biography

Professor Sabatino Cuomo obtained his PhD in Civil Environmental Engineering in 2006, at University of Salerno, Italy. He is the coordinator of LARAM School (International School on "LAndslide Risk Assessment and Mitigation) for PhD students, and a Board Officer for the Italian Chapter of IGS (International Geosynthetics Society). His research topics include landslide mechanisms, solid-fluid transition, landslide dynamics, regional slope stability, slope erosion, geosynthetics reinforcement, laboratory testing of unsaturated soils and constitutive modelling. He has over 100 international publications (mostly peer-reviewed international ISI Journals). He has international cooperation with UPMadrid, UGrenoble, NTNU Trondheim, UGeneve, NorthwesternU Chicago, URijeka, UBeijing. He also serves on Editorial Boards of International Journals, including Soils and Foundations, ICE Journal of Geotechnical Engineering, Bulletin of Engineering Geology and the Environment, Geoenvironmental Disasters.

Theme Lecture

Runout dynamics of long-runout landslides and supporting field evidence

Abstract

The exceptionally long runout of large landslides has inspired a number of hypotheses formulated over the past 130 years to explain the high mobility of these phenomena. To be successful, any hypothesis must include, or at least not contradict, the features observed in the morphological and sedimentological record of the landslide deposit. In this study, we present a comprehensive review of all hypotheses, their historical development, and a simple systematic test against field evidence designed to identify the most feasible of the hypotheses.

Dr. Anja Dufresne

Brief Biography

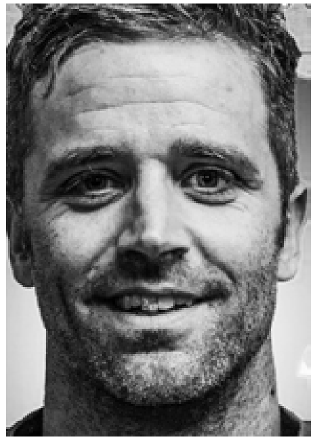
Dr. Anja Dufresne received her PhD from Canterbury University in Christchurch New Zealand, and now serves as assistant professor at the RWTH-Aachen University, Germany. She has been working on natural hazards related topics for more than 12 years, specializing in the emplacement dynamics of large rock avalanches.

Theme Lecture

Impact of climate change and human activity on quick clay landslide occurrence in Norway

Abstract

Landslides in sensitive clays represent a major hazard in many northern countries of the world. Past and recent examples of catastrophic landslides illustrate the extreme mobility of sensitive clays and their hazardous retrogressive potential. This paper uses a new database of landslide in sensitive clays in Norway to assess the influence of weather conditions and human activity on the triggering of quick clay landslides. The paper is a contribution to "what to expect in the future" with climate change. The data suggest that fewer landslides will occur during the dryer summer months in the future, whereas there will be an increase in landslide activity in the spring and fall seasons due to an increase in precipitation and an increase in heavy, sometimes intense, rainfall events. A peak in landslide occurrence is observed in the spring. This peak will likely occur sooner in the year in the future due to higher temperatures, earlier arrival of the spring season and changes in the spring flood patterns. Besides the impact of climate change, the database in itself speaks clearly to geotechnical engineers and policy-makers: in the last decade, 90% of the slope failures link to human activities! Either our knowledge on the behavior of this material is insufficient or, we have not learned from earlier landslide events.



Dr. Jean-Sebastien L'Heureux

Brief Biography

Dr. Jean-Sebastien L'Heureux is a technical lead at the Norwegian Geotechnical Institute (NGI) in Trondheim, Norway. He also recently started as a Professor in Geotechnical Engineering at the Norwegian University of Science and Technology (NTNU). His work focuses on landslide in sensitive clay and on slope stability issues along fjords, and especially on preconditioning and triggering factors for slope instability. He has also a broad experience related to landslide hazard and risk assessment and has participated in several expert committee panels following landslide events. Jean-Sebastien's research integrates knowledge from different disciplines in the context of slope stability (e.g. hydrogeology, geophysics, geology and geotechnical engineering).

Theme Lecture

Toward connecting failure mechanism: numerical investigation of triggering and runout behaviour of rapid landslides

Abstract

Continuous global environmental change, leading to extreme rainfalls and frequent earthquakes, has played an important role in recent geohazard activities. Given that extreme events are becoming the new normal, geohazard activities will become more frequent and disruptive. Among the various geohazards, specifically, rapid flow-landslides stemming from precipitations and earthquakes are troublesome as they often cause considerable casualties and inhibit recovery efforts. In the past decades, owing to the uncertainties of subsurface conditions and numerical tools, many studies on the triggering and kinematic runout behavior are forensic in common; of particular note is that, the connection between prefailure mechanism and postfailure runout process, that is so damaging to recovery efforts and disaster response, is not yet well-investigated. The lecture will illustrate the applicability of an effective and practical approach proposed to ascertain failure mechanism, driving force, initiation time of sliding, and dynamic process of recent rapid landslides. Via case study application, emphasis will be given to disclosing the initiation/post mechanism considering vertical and horizontal seismic accelerations as well as the role of geofluids in the failures.

Dr. Ching Hung

Brief Biography

Dr. Ching Hung has been on the faculty at Department of Civil Engineering, National Cheng Kung University (NCKU) since 2015. In 2018, he has been recognized for extraordinary promise in the early stages of his career and received the MOST Young Scholar Fellowship for the Columbus Program, funded by the Ministry of Science and Technology, R.O.C. (Taiwan). During 2014-2015, he was a Sr. Design Engineer at ASML Holding N.V, since 2017 was a Joint Professor for the Natural Hazard Mitigation & Management, International Master Program (NCKU), and in Summer 2018 was a Visiting Scholar at Disaster Prevention Research Institute, Kyoto University (DPRI, Kyoto University). He has served as a Lead Guest Editor, Editorial Board Member, and reviewer for various quality and SCI-indexed Journals, and has edited a Special Issue stressing on the role and impact of geofluids in geohazards. In 2017, he was also the iYGEC6-Taiwan Delegate, sponsored by the Taiwan Geotechnical Society. Dr. Hung received his PhD from Department of Civil Engineering and Engineering Mechanics, Columbia University in February 2013. During his education, he was awarded the Scholarship from the Ministry of Education, R.O.C. (Taiwan), the NASA National Space Grant Fellowship, the NSF Student Fellowship, and the ISSMGE Foundation Grant.

Theme Lecture

Rain induced landslides in the Nilgiris District of Tamil Nadu, India

Abstract

Rain induced landslides are one of the most common problems worldwide and usually triggered when there is continuous and intense rainfall in areas with steep slopes and less permeable fine-grained soils. Nilgiris is one such district in the state of Tamil Nadu (TN), India which encounters frequent landslides, especially during the monsoon season (October - November) when there is prolonged rainfall. In November 2009, more than 300 landslides occurred in the Nilgiris district following a period of continuous low intensity rain over several days that was followed by high intensity rain. This paper discusses the studies and detailed geotechnical investigation carried out in the Nilgiris slopes following that event. The study revealed that the soil characteristics, rainfall intensity and duration all played a crucial role in triggering the landslides. However, the numerical modelling conducted as part of a detailed geotechnical investigation for one of the critical locations in Marappalam found that the continuous low intensity rain followed by large intensity rain was the main triggering factor for the large landslides in the region. These conditions resulted in a decrease in the matric suction of the soil and the subsequent development of positive pore water pressures, which in turn reduced the shear resistance of the soil resulting in a progressive failure. The detailed investigation carried out comprised mapping of the landslides, topographical survey, as well as field and laboratory tests. Based on the results obtained, it was found that loose and soft soil layers with low permeability also contributed to the large scale of the slope failures. Failure mechanisms for the landslides were identified from the numerical analysis using landslide simulation program LS-RAPID. The failure mode, travel distance and area of landslide observed from the simulation were found to be conforming with the observed motion from the topographical survey.

Dr. V.B. Maji

Brief Biography

Dr. V.B. Maji, presently working as Associate Professor in the Department of Civil Engineering, Indian Institute of Technology (IIT) Madras. He has joined the institute as Assistant Professor in the year 2008. He has received his PhD degree from Department of Civil Engineering, Indian Institute of Science Bangalore for the thesis titled "Strength and deformation behaviour of jointed rocks: An equivalent continuum model" in the year 2007. Prior to that he has a Master of Technology degree from Department of Mining Engineering, Institute of Technology (Now IIT), Banaras Hindu University (BHU), India with Rock Mechanics specialisation (year, 2003) and a Bachelor of Science Engineering degree in Mining Engineering from BIT Sindri, Dhanbad, India (year 2001). He has more than 13 years of experience in research/teaching and has published more than 60 papers in various international/national journals and conferences.

Theme Lecture

Numerical simulations of dynamic behaviour with differently shaped slope models using the MPS method

Abstract

Geo disasters seriously damage infrastructure equipment and cause heavy economic losses. To reduce this damage, there is a need to evaluate not only stability but also dynamic behavior of landslide body. FEM is a recognised method used to evaluate slope stability, however it faces difficulties approaching complicated phenomena, such as the large deformation problem, which involves mesh twisting and distortion. In large deformation problems, remeshing processes are needed during the calculation; this increases the complexity of the computer program and reduces calculation precision.

For solving those problems, we develop particle method named MPS (Moving Particle Semi-implicit method). MPS is mesh-free methods based on Lagrangian descriptions and suitable for simulating complex phenomena, such as a moving boundary, free surface problems, and large deformation problems. In addition, MPS is combined with discrete continuum of particles to solve continuum equations. Therefore, MPS is categorized as continuum analysis methods.

In my lecture, I will talk about calculation method of MPS. In addition, numerical simulations were conducted for several models with varied slope shape and compared dynamic behavior.

Dr. Shintaro Nohara

Brief Biography

Dr. Shintaro Nohara is currently a researcher in Civil Engineering Laboratory, Central Research Institute of Electric Power Industry (CRIEPI), Japan. He obtained Bachelor and Master's degree in geotechnical field from Okayama University, Japan. His specialization is geotechnical engineering and groundwater engineering. His research interests include (1) numerical modelling of landslide and regional groundwater flow, (2) 3D microscopic modelling of geo-materials, (3) development of in-situ trace test for evaluating solute transport process.

Theme Lecture

Sensitive clay flowslides: from rupture to propagation

Abstract

Sensitive clays, mostly found in Eastern Canada and Scandinavia, are renowned for their large landslides, such as lateral spread failures and multiple retrogressive landslides, also known as sensitive clay flowslides. Debris from sensitive clay flowslides has a high mobility, with run-out distances that may extent hundreds of meters in relatively flat terrain and non-channelised environment, and kilometers in channelized terrains. Sensitive clays are leached glaciomarine clay deposits that are relatively stiff, but, when remolded, will exhibit a great reduction in the shear strength, and will flow as a viscous material. Up to now, landslide runout zonation was mainly carried out using empirical relationships. Some numerical modelling was also performed in the recent years using back-calculated rheological parameters, but these studies are of little help in the context of hazard mapping. In this presentation, we will investigate the behaviour of the clayey material between an intact state to the remolded state. Following the remolding, some rheological characteristics of sensitive clays will be discussed. Finally, new advancement in the numerical modelling of sensitive clay flowslides will be presented, using case studies. In that sense, we are now trying to incorporate in situ geotechnical and rheological characteristics of the deposits in order to calculate the runout extend of sensitive clay flowslides. In order to do so, the energy needed to remold the material need to be taken into account in the modelling.

Dr. Dominique Turmel

Brief Biography

Dr. Dominique Turmel is a geological engineer specializing in the field of sediment transport, geohazards and geotechnics. Since obtaining his doctorate, he has been acting as a research associate supporting the research activities of the Natural Risks Studies Laboratory at Laval University. In recent years he has worked on various projects involving the study of sediment transport mechanisms, landslide analysis and their associated consequences such as tsunamis, post-failure analysis, and numerical modelling of these different phenomena. His current research interests gravitate around the post-failure landslide behaviour, particularly in understanding the transition between the intact and remolded state of clay, their rheological characterisation and numerical modelling of the post-failure phase of sensitive clay flowslides.

2018 Benchmarking Exercise on Landslide Runout Analysis

Introduction

Prediction of landslide motion distance and velocity is required for hazard and risk assessment and for the design of associated mitigation measures. The goal of such predictions is to estimate the area that could be affected by the movement of a landslide and to map hazard intensity parameters, in particular the volume, velocity, depth of flow and thickness of landslide deposits.

In the time since the first Benchmarking Exercise of Landslide Runout Analysis held in Hong Kong in 2007 (see QR Code on page 44), the technology for making such predictions has developed substantially. A number of different numerical techniques and computer-based models now exist, each capable of simulating the motion of a given volume of unstable material from its source on a hillside to a deposition area below. Many of these models are even capable of simulating debris-structure (e.g. debris-resisting barriers) interaction. As this technology continues to mature, it is useful to once again compare and benchmark the various models against one another.

The Organising Committee of the Second JTC1 Workshop has decided to devote a half-day session at the Workshop to a review of the current state-of-the-art of landslide dynamics modelling. The Benchmarking Exercise is not a competition. Its purpose is to assess whether this field of science is on its way towards establishing some degree of commonality between methods used by various experts in the subject. It is felt that runout prediction can only be regarded as reliable once certain convergence of modelling philosophies and methods begins to emerge amongst various groups specialising in the subject.

Benchmarking Cases and Data Supplied to Participants

The Benchmarking Exercise Review Sub-committee selected four examples of past natural landslides and two hypothetical prediction cases (see Table 1). All the past natural landslides cases involve long-runout flow-like landslides involving different types of materials or far-reaching debris floods, moving at extremely rapid velocities. The following data are available for each case:

1) A digital elevation model encompassing the landslide rupture surface, path and deposition area (or a contour map showing the elevations of the pre-landslide topography).

2) A vertical thickness map of the landslide source (or a contour map showing the elevations of the post-landslide topography; for debris flood cases, inflow hydrograph of the debris flow will be given with debris concentration and location of the inflow specified). Source volume is understood here as the volume between the rupture surface and the original pre-slide ground surface.

3) Description of the landslide. Available information e.g. surficial and bedrock geology, engineering-geological description of the materials forming the landslide source path and deposit, areal distribution of different material covers within the path, comments on ground and surface water, land use and weather at the time of occurrence is presented in the description. Photos of each site are also provided, if available.

4) A map showing the outline of the final landslide deposits and the outline of any material entrainment areas along the path, both subject to data availability. Where possible, thickness distribution of final deposits and entrainment zones eroded by the landslide are provided in the form of contours, or at least as spot values.

5) A summary of all existing information regarding the behaviour of the landslide are given, particularly observed or estimated movement velocities or movement duration, as far as available.

Table 1 List of benchmarking cases

Group A - Rock avalanches	
A1	The Goldau rock avalanche in Switzerland
Group B – Mudflows	
B1	Popocatépetl volcano muddy lahars
Group C – Debris flows	
C1	2008 Yu Tung Road debris flow, Hong Kong
C2	Johnsons Landing debris avalanche, Canada
Group D - Hypothetical prediction cases	
D1	A historical hillside catchment in Hong Kong
D2	A potential rock avalanche site in Canada

Details of the benchmarking cases are given below.

Group A – Rock Avalanches: Goldau Rock Avalanche

The following is an excerpt from Aaron (2017).

The Goldau Rock Avalanche occurred in Central Switzerland in 1806. This tragic event claimed 457 lives, destroyed 111 houses and triggered a 20 m high wave in nearby Lake Luarez. The failure involved the detachement of 35 – 40 × 10^6 m^3 of material along a planar rupture surface of a dip slope in marlstone and conglomerate (Fitze, 2010). A detailed investigation of the geology and future hazard potential is given by (Berner, 2004). A contemporary photo of the source area is shown in the figure below. Numerical modelling of the failure mechanism is described by Thuro et al. (2006). It was found that the rupture surface exploits highly weathered marlstones near the main scarp, and then cuts through conglomerate layers lower down. Friction angles of about 23° were found within the weathered marlstone and evidence of brittle fracture was found within the conglomerates. Based on this, it was suggested that the slope was near limit equilibrium conditions and progressive failure through the conglomerates initiated brittle failure of the whole sliding mass along a rupture surface parallel to the bedding planes.

The topography files and simulation constraints are the same as those used in the analysis documented by Fitze (2010), based on a DEM obtained from SwissTopo. It contains three rasters: the path topography, the thickness of debris in the source zone and the impact area of the rock avalanche. It should be noted that the impact area only shows that area where the rock avalanche deposited, and does not include the large splash zone that surrounds the deposit and triggered a wave in Lake Luarez.

Photo of the Goldau source area.

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Fitze, P. (2010). *Runout analysis of rapid, flow-like landslides.* Master's Thesis. Hochschule für Technik Rapperswil.

Thuro, K. K., Berner, C., & Eberhardt, E. (2006). *Der Bergsturz von Goldau 1806 - Was wissen wir 200 Jahre nach der Katastrophe?* Bull. Angew. Geol., 11(2), 13–24.

Group B – Mudflows: Popocatépetl lahars

Popocatépetl volcano (19˚1’ N, 98˚37’ W; 5450 m) is located 70 km southeast of Mexico City (population 24 million) and 45 km west of Puebla (population 4million) (Fig. 1). Popocatépetl is an active andesite stratovolcano having very destructive eruptive phases. During the 9th century, large Plinian eruptions triggered lahars that flowed for tens of kilometers from the volcano (Siebe et al., 1996). Minor sub-Plinian eruptions also occurred during the 14th, 16th, and 18th centuries, and in the early 20th century (Robin, 1984). The volcano has been almost permanently active since December 1994, involving alternating formation of lava domes in the interior of the crater and their destruction by limited strombolian and sub-Plinian explosions. The northern face of Popocatépetl volcano was covered by a glacier that predated the Spanish conquest in 1519 CE, although its maximum extent was reached in the late 19th century as a result of the Little Ice Age (LIA) advance and the low level of previous volcanic activity. Analysis of the ends of the terminal moraines indicates a minimum altitude of 4150 m for the glacier front at that time. Since then the glacier has retreated, mainly because of increased temperatures (Delgado, 1997), from an area extent of approximately 3 km² to 0.59 km² in 1992, when the minimum altitude was 4694 m (Palacios, 1996).

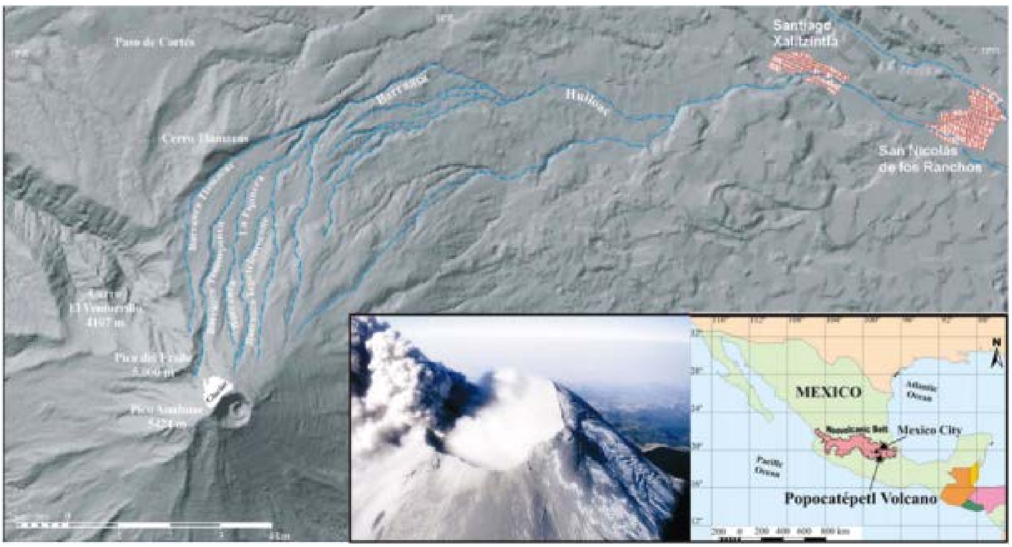

Fig. 1. Shaded relief map of Popocatépetl volcano and surrounding areas with main drainage systems

Sudden melting of the glacier during past volcanic activity triggered two large lahars. On 1 July 1997 the glacier was covered with pyroclastic fallout, which increases glacial melting due to albedo reduction (Capra et al., 2004). The meltwater remobilized materials filling the valley head, and formed a single lahar event that transported 180,000 m^3 of a mixture of water and materials (Muñoz-Salinas et al., 2009b), including boulders larger than 2 m in diameter, at a velocity of 1.3 – 7.7 m/s (Muñoz-Salinas et al., 2007). The lahar flowed down Huiloac Gorge and through the towns of Santiago Xalitzintla and San Nicolas de los Ranchos, covering a total runout distance of 17 km. The lahar was characterized by hyperconcentrated flow at the start and end of its path, and debris flow in the intermediate sector (Capra et al., 2004).

On 22 January 2001 the destruction of a dome inside the crater triggered a pyroclastic flow that crossed the glacier and flowed down through the drainage gorges. The flow abraded the glacier and triggered the melting and release of 717,000 m^3 of water, based on calculations from photogrammetry records of the reduction of the mass of the glacier (Andrés et al., 2007). Four hours later a lahar was initiated in the valley head areas; this carried the pyroclastic flow materials down Huiloac Gorge for approximately 14 km to the immediate surroundings of Santiago Xalitzintla. The lahar transported 160,000 m^3 of material, including 68,000 m^3 of water (Muñoz-Salinas et al., 2009b), and reached a maximum velocity of 13.8 m/s that decreased to 1.4 m/s at 9.5 km from its starting point (Muñoz-Salinas et al., 2007). This lahar behaved as a debris flow throughout its course (Capra et al., 2004). Initial lahar volume was estimated by different methods (Sheridan et al., 2001 and Muñoz-Salinas et al., 2009) leading to oscillating values from 1.85 to 3.30 $\times 10^5$ m^3 for 1997 lahar and 1.57 to 2.44 $\times 10^5$ m^3 for 2001 lahar.

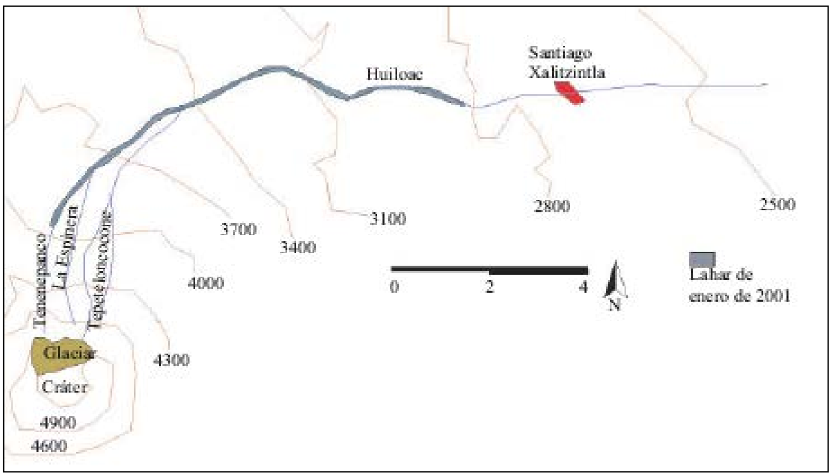

Fig. 2. Runout of 2001 lahar (E.Muñoz 2004)

The topographical data used in this study were obtained during field work carried out in February and October 2002 as part of ongoing research (San José et al., 2007; Muñoz-Salinas et al., 2008). As the channel landforms indicating the maximum inundation level and the deposits resulting from the 2001 lahar were well preserved, a series of channel cross sections showing the form deposit depth and the maximum flow height reached in the stream bed during this event could be precisely described. The first step in producing these cross sections was leveling, following the thalweg, to mark the locations selected for the cross section profiles. Leveling was carried out using a compass, leveling rod, measuring tape, and differential GPS to obtain the coordinates of the intersection points of the leveling (longitudinal profile) and transverse profiles. To draw each profile, a point on the thalweg was selected and the x, y, and z coordinates were obtained using differential GPS (error ± 3 cm). The extremes of each profile were then established on the channel sides. Measurements were made using a Leica TCRM 1102 PLUS total station; the profile points in Huiloac Gorge were determined without the use of a prism, so that the profile error varied 1–2 cm, with a maximum error ± 2 cm. The profile showed the deposit depth and the maximum height of the 2001 lahar flow, deduced from deposits and abrasion surfaces, as indicators of maximum inundation level.

All data were uploaded from the station to AutoCad, generating .dwg format files. This software was used to draw comparable profiles on an x–y axis. The AutoCad files were then exported to ArcGis, and the respective .shp files were created for each cross section. When the triangular irregular networks (TINs) had been generated in ArcGis, the differences between the field data and simulations were calculated using the surface analysis cut/fill tool in the 3D Analyst extension. The result identified the differences between the real and simulated areas.

The attributes of the cut/fill layer dataset were imported into a spreadsheet for calculation of the volume differences.

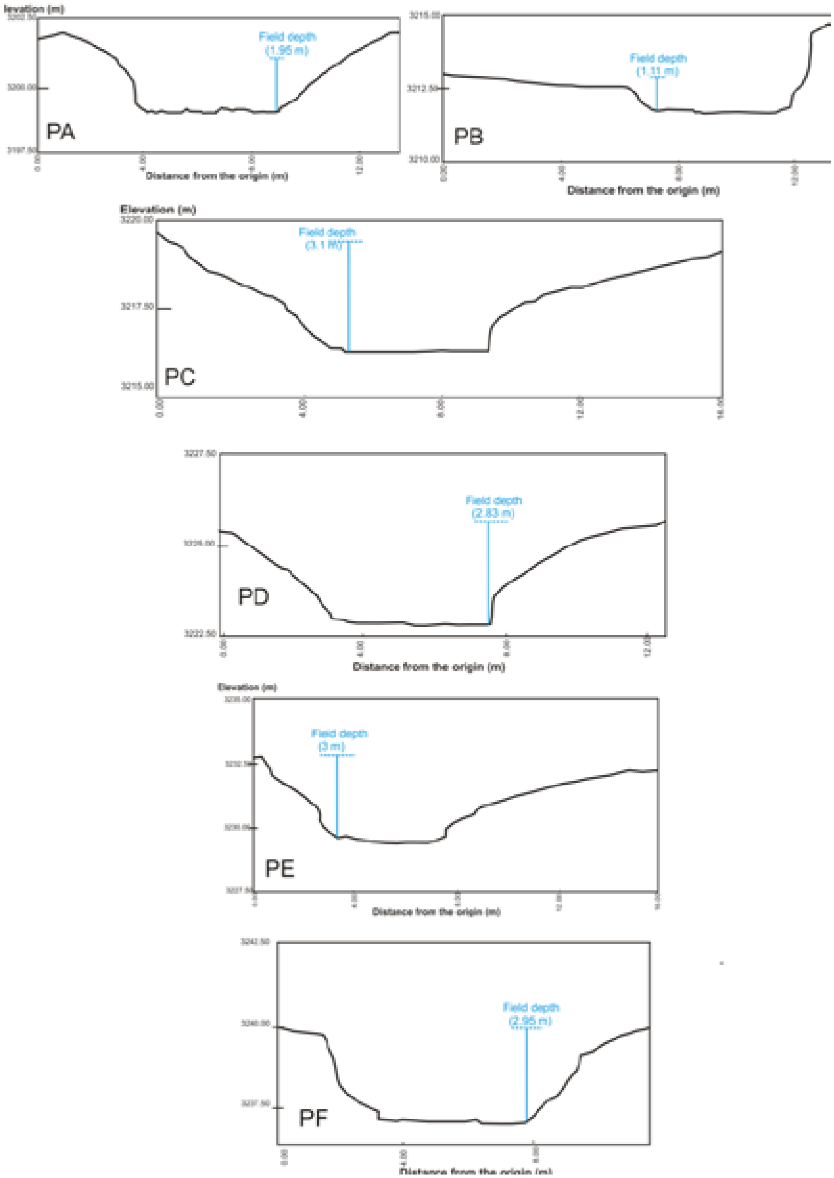

Fig. 3. Field depth along the Tenenepanco-Huiloac junction zone (from Haddad et al. 2016)

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Group C – Debris flows:
(1) Debris flow above Yu Tung Road, Hong Kong on 9 June 2008

The June 2008 Yu Tung Road debris flow event involved a single landslide source. The landslide debris reached Yu Tung Road, resulting in serious road blockage. About 2,350 m^3 (i.e. the landslide source area No L25 mentioned on page 9 of the "Detailed study report of Case C1.pdf") of debris detached from the source location, which had a runout distance of about 600 m, and all the debris reached the Yu Tung Road. The lower portion of the debris flow was captured on video by a member of the public, which is hosted in Youtube at https://www.youtube.com/watch?v=R2uTKyK1c9k.

The velocity of the debris was estimated to be about 12 m/s at chainage = 100 m based on the super-elevation data measured. The measured velocity data beyond chainage = 400 m is based on both the super-elevation data and the video footage mentioned above. The figure below shows the record of frontal velocities of this debris flow event.

In the numerical back analysis, the participants are required to produce a profile plot that present both the computed frontal velocities and the measured velocities for comparison. Also, the participants are required to demonstrate that the simulated landslide debris could reach the road. Since, the final deposit profile of this landslide case was not available, it is not required to conduct comparison between computed and measured deposit profiles.

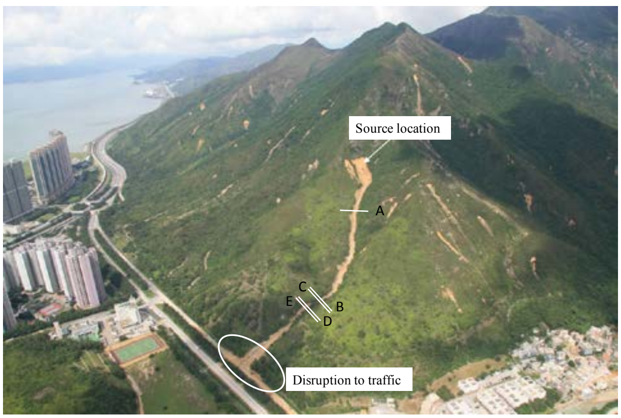


Fig. 1. Aerial View of the debris flow event above Yu Tung Road taken on 9 June 2008

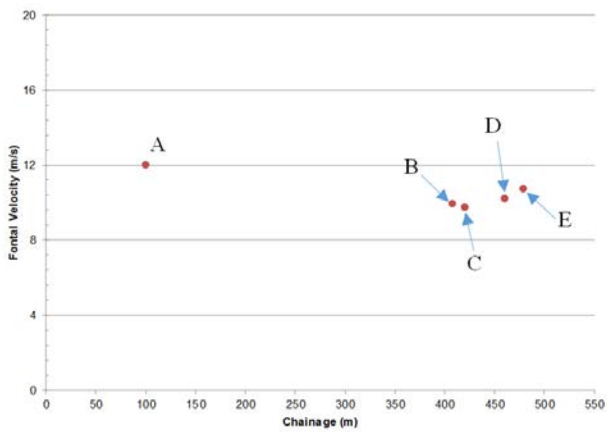


Fig. 2. The record of frontal velocities of the 2008 Yu Tung Debris Flow (Please see Fig. 1 for the approximate locations of velocity records)

Group C – Debris flows:
(2) The Johnsons Landing Landslide

The following is an excerpt from Aaron (2017).

The Johnsons Landing debris avalanche occurred on July 12th 2012 about 2 km northeast of the small community of Johnsons Landing, located on Kootenay Lake. An image taken soon after the debris avalanche is shown in Figure 1. This tragic event claimed four lives (Nicol et al., 2013).

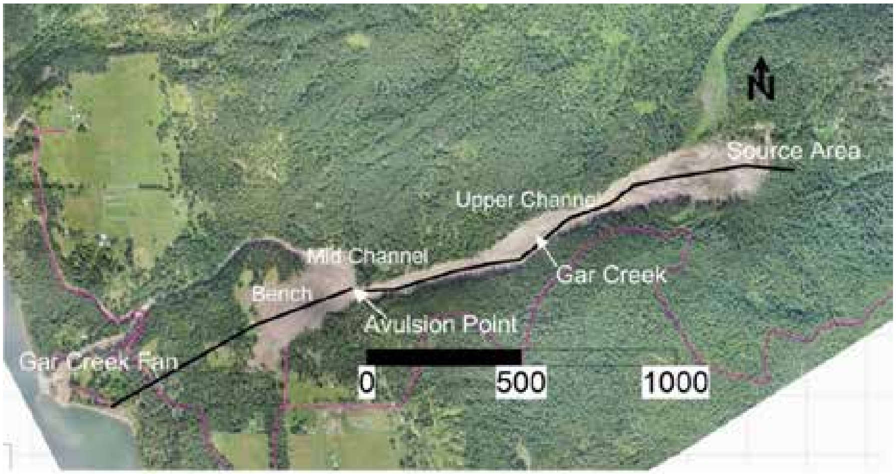


Fig. 1. Overview of the Johnsons Landing debris avalanche. Image: Province of British Columbia, Copyright © Province of British Columbia.

As shown in Figure 1, the debris avalanche was initially confined in a channel (Gar Creek). Just above the community of Johnsons Landing, this channel has a 70° bend (the bend is labelled 'avulsion point' on Fig. 1). Debris flows have been occurring repeatedly in the Gar Creek drainage, but they have always followed the curving path of the gully. A debris fan built up at the mouth of the gully, labelled 'Gar Creek Fan' on Fig. 1. The 2012 debris avalanche avulsed from the channel at this bend, spread out over the terrace surface and destroyed three homes located on the Johnsons Landing bench (the location of the bench is shown on Fig. 1.)

During the investigation following this tragic event, test pits were excavated through the debris on the bench. These test pits did not show any evidence of other landslide deposits on the bench since deglaciation (Nicol et al., 2013). The 2012 event was therefore the first event to over-run the sharp bend and impact this bench in at least 7,700 years (Nicol et al., 2013).

An in-depth investigation was conducted by Nicol et al. (2013) immediately following the Johnsons Landing debris avalanche. Previous terrain maps had identified the source zone, which is composed of glacial sand and silt, as a zone of instability, subject to multiple rotational sliding ("Failing" designation of the terrain polygon). This previously disturbed material failed following a rain-on-snow event (Nicol et al., 2013).

Nicol et al. (2013) provides estimates of source and deposit volumes. These estimates are based on a reconstruction of the pre-event topography made using photogrammetry, and adjusted to be consistent with test pits excavated in the debris field. It is estimated that the source volume was 320,000 m^3 and the deposit volume was 364,000 m^3. This discrepancy in source and deposit volume can be attributed to inaccuracies in the volume estimates, as well as bulking of the debris after failure. Nicol et al. (2013) divides the deposit into three zones: The bench, the mid channel and the upper channel. These zones are shown on Figure 1. It was estimated that 169,000 m^3 of material deposited on the bench, 55,000 m^3 deposited in the mid channel and 140,000 m^3 deposited in the upper channel. Rough velocity estimates based on superelevation data, as well as an eyewitness account, indicate flow velocities of between 25-35 m/s as the landslide travelled down the channel (Nicol et al., 2013).

One key constraint on the dynamic analysis is that only about 5% of the material from the initial failure travelled through the sharp bend and all the way down the channel to the fan during the initial catastrophic debris avalanche. This observation is based on an investigation performed on the day of the debris avalanche (Nicol et al., 2013). A subsequent failure on July 13th resulted in a significant amount of debris and timber moving down the established channel and depositing in Kootenay Lake. A video of this secondary landslide is available online: https://www.youtube.com/watch?v=n1cCs-S5EKc

The geometric data is based on a post-event Digital Elevation Model (DEM), modified to approximate pre-event conditions by Nicol et al. (2013). The accompanying excel file (Digital data (Johnsons Landing).XLSX) contains X,Y coordinates of the path of the debris avalanche, the thickness of material in the source zone, and the impact area of the event.

References:

Aaron, J. (2017). *Advancement and Claibration of a 3D Numerical Model for Landslide Runout Analysis*. PhD thesis, University of British Columbia.

Nicol, D., Jordan, P., Boyer, D. & Yonin, D. (2013). *Johnson's Landing Landslide Hazard and Risk Assessment*. Regional District of East Kootenay.

Group D – Hypothetical prediction cases:
(1) A historical landslide catchment in Hong Kong

A landslide occurred on the hillside of Tates's Cairn, Hong Kong on 22 August 2005. Landslide debris developed into a debris flow in an incised natural drainage line. The maximum active volume of the debris flow is about 1,000 m^3. Detailed field mapping after the landslide revealed a distressed hillside immediately adjacent to the source area of the landslide. The ground mass associated with the distressed hillside could be of a volume of 10,000 m^3.

Summary of key information for the 2005 Landslide at Tates' Cairn, Hong Kong:

(a) The landslide occurred after heavy rainfall. A total volume of about 1,000 m^3 was completely detached from the landslide source, debris entered into a natural drainage line.

(b) Debris splatter was also observed on the trees alongside the trail with some debris splatter reaching several metres up the trees trunks and on branches. The extent of the debris splatter suggests wet debris probably travelling in a turbulent manner.

(c) Debris was stopped by a pre-existing boulders dam at a distance of about 330 m, measured from the landslide source. The pre-existing boulders dam was formed by previous debris flows in 1963.

(d) A sharp change of debris flow direction at about CH220 (see Figure 1 below) resulted in a super-elevation of about 7.8m up the eastern flank of the drainage line.

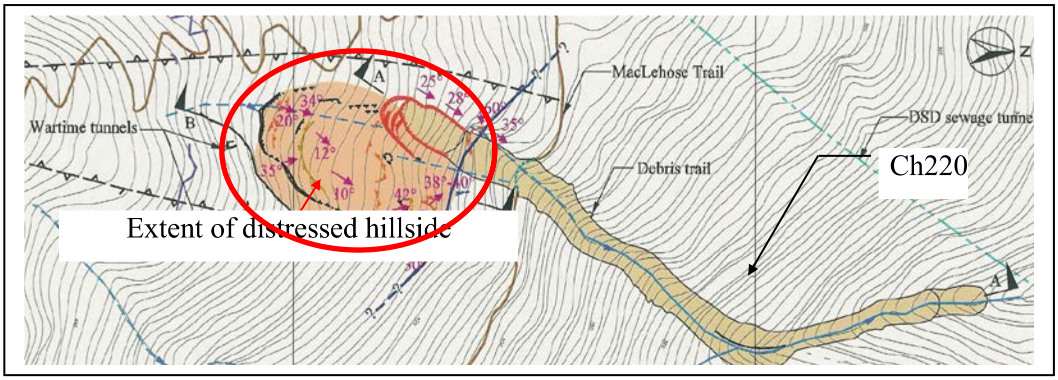


Fig. 1. Plan view of 2005 debris flow and extent of distressed hillside

Assuming that the 10,000 m^3 ground mass of the distressed hillside detaches and develops into a debris flow along the natural drainage line, discuss how the input parameters, especially the flow resistance parameter(s), for use in the numerical prediction should be established. A copy of GEO Technical Guidance Note 29.pdf (https://www.cedd.gov.hk/eng/publications/guidance_notes/doc/TGN29_1.pdf) for estimating the mobility of the landslide debris adopted in Hong Kong's practice is also provided for reference.

With the established flow resistance parameter(s), carry out forward predictions of the mobility dynamics of the debris flow developed by the detachment of the 10,000 m^3 ground mass for the following 2 cases:

(a) assuming entrainment occurs and the entrainment volume is 10,000 m^3 when the debris front reaches the road (see Point A shown on Figure A.1), and

(b) assuming entrainment does not occur.

Please report the following for the above 2 forward prediction analyses:

(a) Velocity hydrographs at Points A, B and C (see Figure A.1);

(b) Debris thickness hydrographs at Points A, B and C (see Figure A.1);

(c) Time history of average velocity of landslide debris along the flow path;

(d) Time history of active volume (i.e. source volume + entrained volume) of landslide debris along the flow path;

(e) Profiles of landslide debris throughout the flow process (can be presented in plan view); and

(f) Consequence(s) of the landslide (e.g. will landslide debris reach the road and the buildings at the downstream of the road (see Figure A.1)).

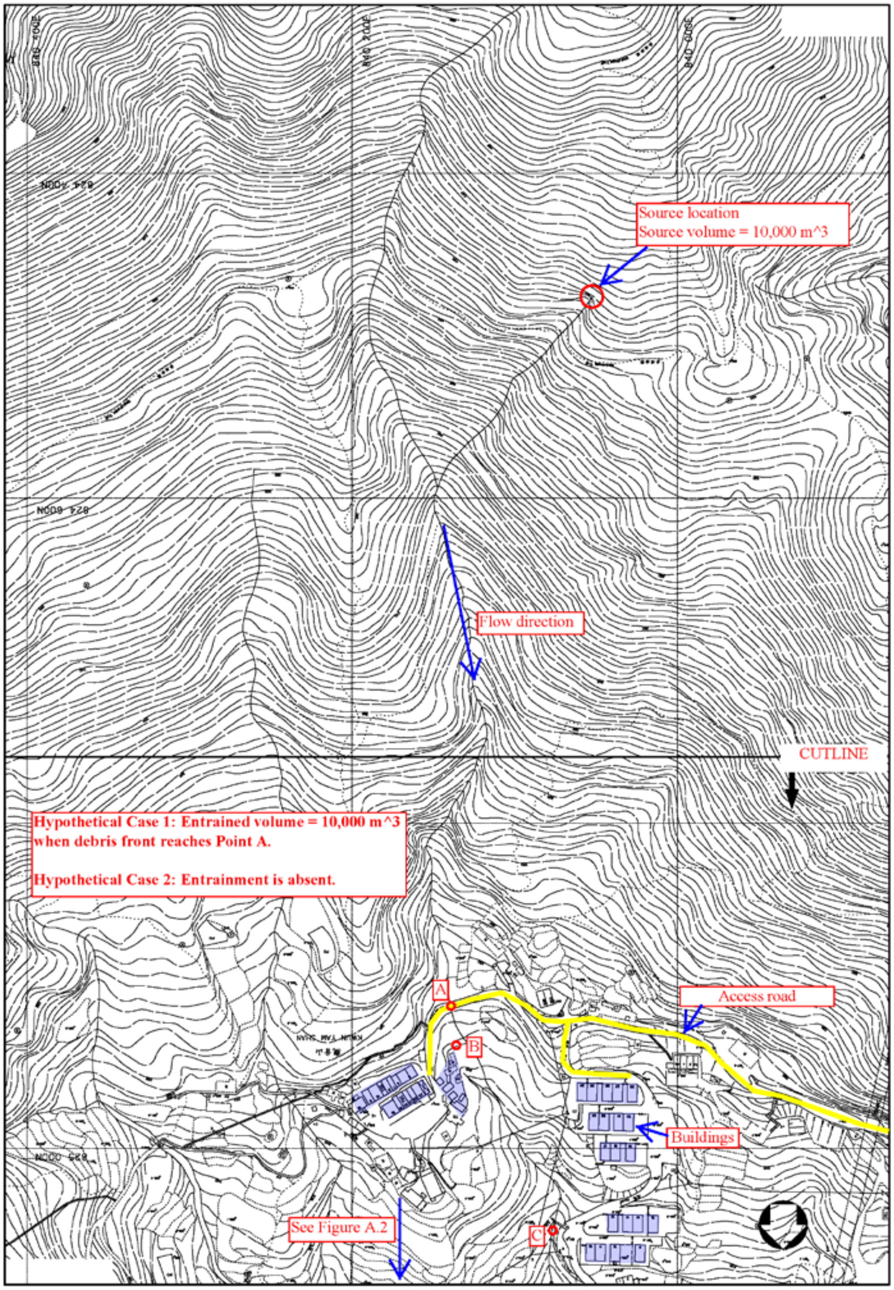


Fig. A.1. Location map (Part 1 of 2)

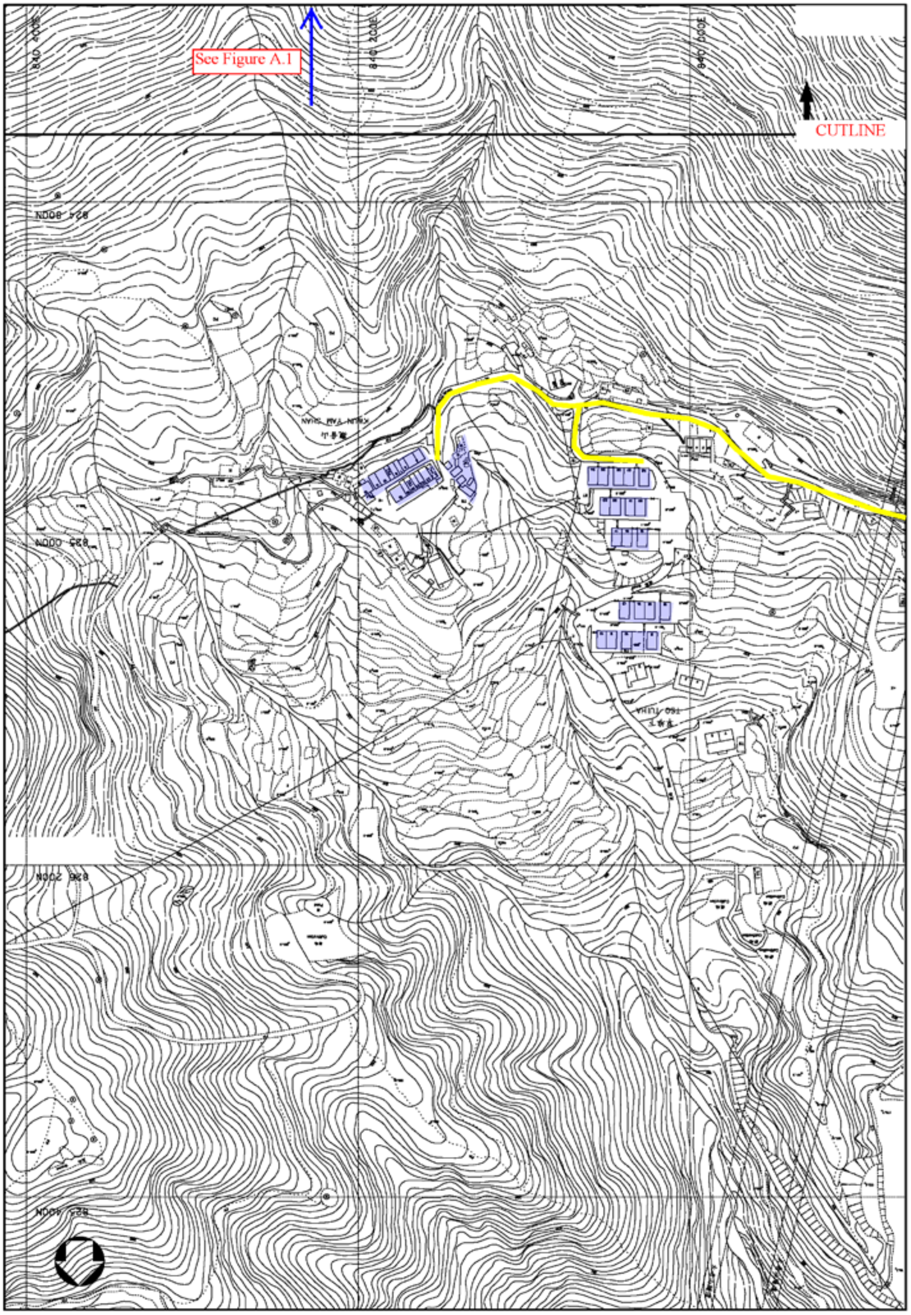


Fig. A.2. Location map (Part 2 of 2)

Group D – Hypothetical prediction cases:
(2) A potential rock avalanche site in Canada

This site has been identified as having a rock avalanche hazard. The source area is along a range of mountains, with a broad valley below, that has been shaped through the actions of Pleistocene glaciation and more recent fluvial activity. The area has wet winters, which results in debris flows and the associated accumulation of material at the base of the slope. The general surficial geology of the site is shown in Figure 1.

The source zone material is composed of fine to medium grained diorite that has a well-developed, steeply dipping foliation. Source volumes were estimated based on a kinematic analysis, with the basal release surface governed by a joint set that has medium persistence (0.5 – 10 m) and moderate to wide spacing (0.2 – 1.0 m). The travel path consists of a steep slope that is partly mantled with landslide debris, as well as a flatter valley bottom filled with a combination of fluvial and glaciofluvial sediments. For the forward prediction scenario, an unbulked unstable volume of 8.3 Mm^3 of material is considered.

The geometric data consists of two sets of raster data. The first contains the path topography of the potential rock avalanche, and the second contains source thickness estimates.

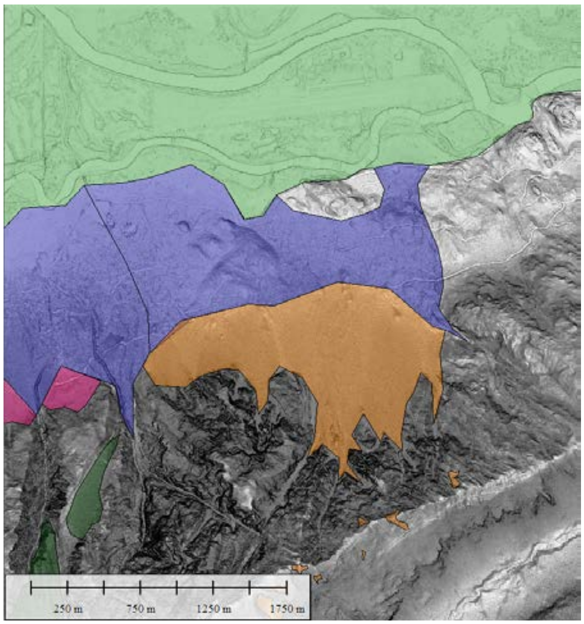


Fig. 1. Surficial geology for the hypothetical rock avalanche runout zone.

Review Report and Submissions

Participants of the Benchmarking Exercise use their landslide mobility model(s) to simulate any of the benchmarking cases. Results of the simulations e.g. landslide affected zones at different times after onset of landslides, debris thickness and velocity-time profiles are submitted to the Benchmarking Exercise Review Sub-committee. The Review Sub-committee has compiled a Review Report summarising key information including types of model used, simulation results and assumptions made by different participants, and salient observations noted from submissions. All submissions sent to the 2018 benchmarking exercise and the Review Report can be accessed from the following link:

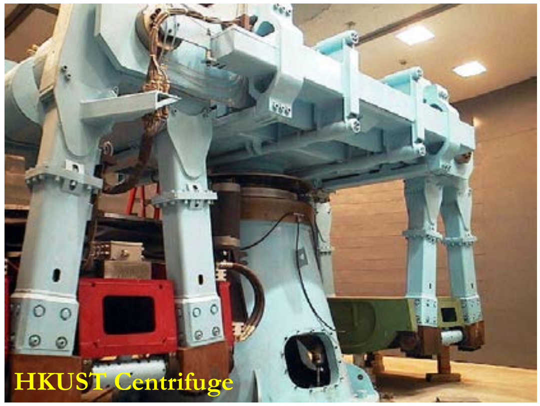
http://www.hkges.org/JTC1_2nd/paper.html

The 2007 Benchmarking Exercise on Landslide Runout Analysis in Hong Kong can be also accessed from the following link:

https://bit.ly/2PCMy85

Technical Visits

Option 1: Geotechnical Centrifuge Facility at HKUST


HKUST Centrifuge

The Hong Kong University of Science and Technology houses a 400 g-ton, 8 m diameter beam centrifuge, which has been used extensively in research and teaching. A wide range of geotechnical problems can be modelled physically using this facility, some of which include rain-induced landslides, consolidation settlement of reclaimed lands, seismic ground response, shallow and deep foundation behaviour, the tunnelling and excavation processes, etc. Several state-of-the-art devices have been developed, including a four-axis robotic manipulator, a biaxial shaking table, an energy-harvest testing chamber, a hydrodynamic loading system, and an environmental chamber.

The present beam centrifuge can operate at up to a maximum centrifugal acceleration of 150 g with a payload of 2.7 tons. The largest models are 1.25 m in length and 0.85 m in height and the largest prototype dimensions are 188 m in plan and 128 m in height. Currently the centrifuge serves over 60 PhD and MPhil students from HKUST and other local universities.

Option 2: Debris-resisting Barriers at Yu Tung Road


Debris-resisting Rigid Barrier

Following a heavy rainstorm on 7 June 2008, about 50 landslides occurred on the hillside above the North Lantau Expressway and Yu Tung Road on Lantau Island. In the aftermath of the landslides, a series of mitigation measures were implemented in the area. These included debris-resisting flexible and rigid barriers installed at various catchments. In some case, arrays of baffles are installed to dissipate flow energy impacting on barriers. These designs were optimised based on landslide mobility assessment.

Landscape design was also incoporated in these natural terrain mitigation works, to minimise potential visual impacts of the proposed engineering structures and to blend in the structures with the surrounding area.

Option 3: Headquarters of Geotechnical Engineering Office (GEO)

Since its establishment in 1977, the Geotechnical Engineering Office (GEO) has strived to tackle landslide problem by developing a comprehensive slope safety system to effectively monitor and manage landslide risk through the implementation of multi-pronged strategies. The overall landslide risk in Hong Kong has been remarkably reduced to less than one-quarter of the risk level in 1977. Casualties due to landslides have also dwindled significantly in recent years.

Emergency Control Centre

Participants will be briefed on the Hong Kong Slope Safety System and some of its key components, including the Landslip Warning System, Landslide Emergency Services and Landslip Prevention and Mitigation Programme. Participants will also visit GEO's Emergency Control Centre and the Geotechnical Information Unit of the Civil Engineering Library, which houses a comprehensive collection of geotechnical data from ground investigations throughout the territory of Hong Kong.

Time	Topic/Programme	Responsible by
14:00 – 14:15	**Welcoming and Photo-taking**	**W K PUN** Head of GEO
14:15 – 14:45	**Presentation Session (with Q&A)** 1. Hong Kong Slope Safety System • History of landslides in Hong Kong • Landslide risk reduction strategies • Challenges ahead	**Lawrence SHUM** Senior Geotechnical Engineer
14:45 – 15:15	2. Landslip Warning System • Details of the landslip warning system • Details of the natural terrain landslip alert	**Vickie KONG** Geotechnical Engineer
15:15 – 15:30	**Coffee Break**	
15:30 – 16:00	3. Landslide Emergency Services • GEO's landslide emergency services • Facilities and equipment • New initiatives and way forward	**Becky LUI** Senior Geotechnical Engineer
16:00 – 16:30	4. Landslip Prevention and Mitigation Programme • Upgrading of man-made slopes • Landscaping and ecological enhancement in slope works • Po Shan Drainage Tunnel	**Alan WONG** Senior Geotechnical Engineer
	Guided Tour	
16:30 – 17:00	• Emergency Control Centre • Landslip Preventive Measures Division • Civil Engineering Library	

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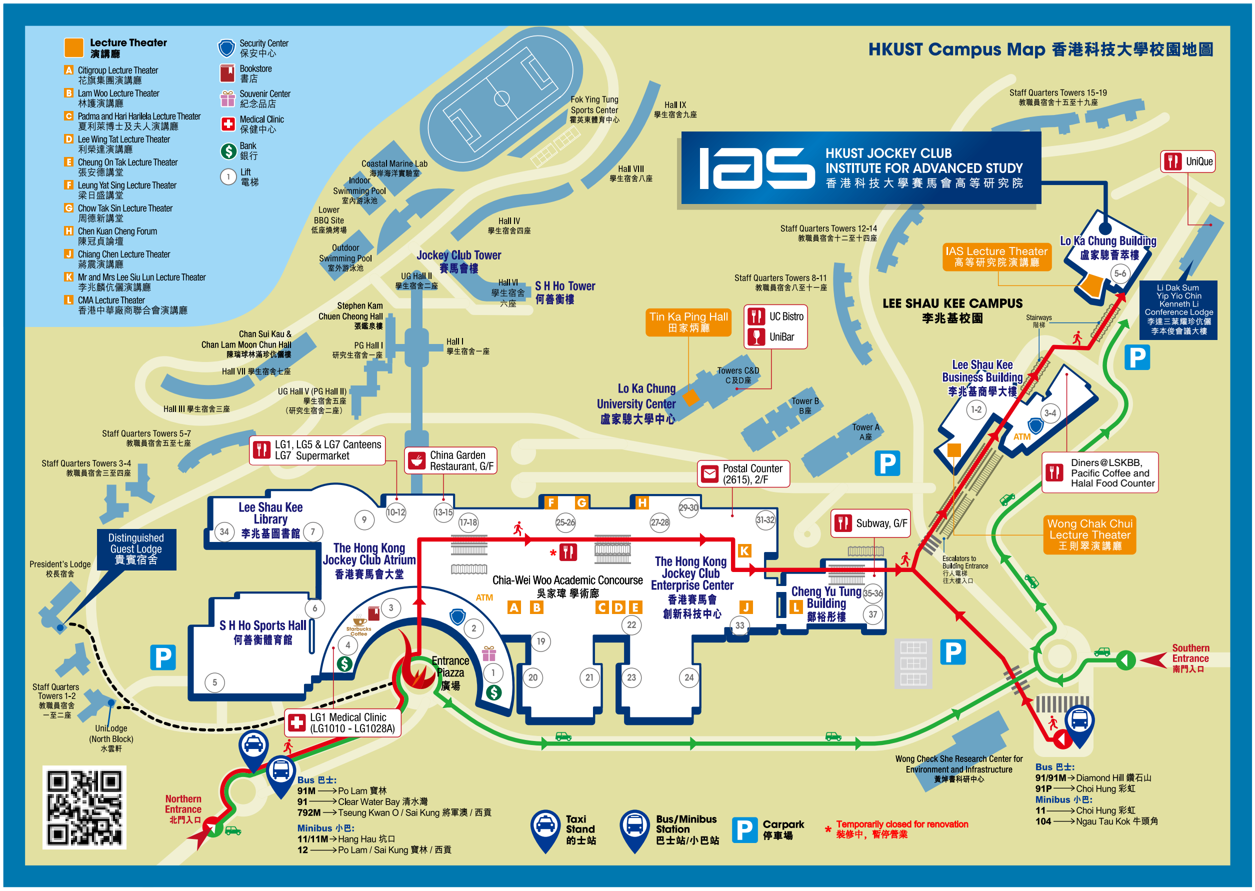

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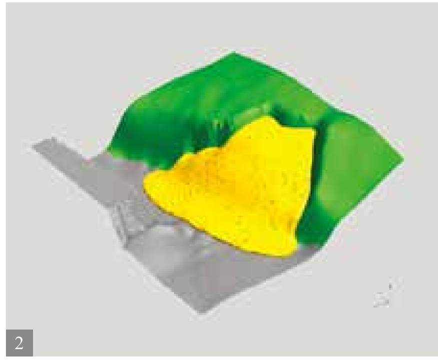

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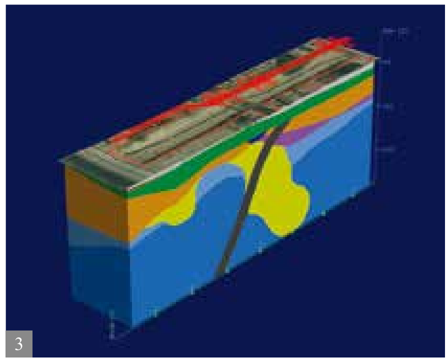

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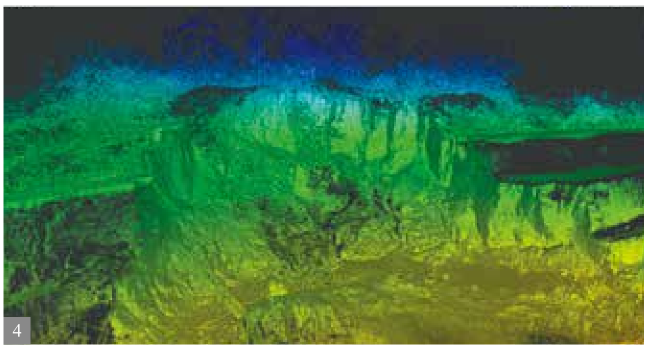

4

Image

1. Landslide Assessment in Sierra Leone
2. Debris Mobility Modelling using LS-DYNA
3. Enhanced 3D Ground Modelling using Leapfrog
4. Mobile Laser Scanner used in Penang Landslide Investigation

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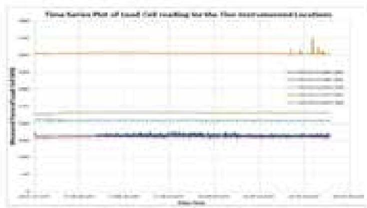

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