Volume 54 November 2017 Special Issue

JOURNAL OF NEPAL GEOLOGICAL SOCIETY

ABSTRACT VOLUME

11TH IAEG ASIAN REGIONAL CONFERENCE (ARC-11)

November 28-30, 2017

Kathmandu, Nepal

11th IAEG Asian Regional Conference (ARC-11)

"Engineering Geology for Geodisaster Management"

November 28-30, 2017

Kathmandu, Nepal

Organized by

Nepal Geological Society

Organizing Committee

Chair: Dr. Kabi Raj Paudyal, President, Nepal Geological Society

Convener: Dr. Danda Pani Adhikari, Tribhuvan University

Co-Convener: Dr. Ranjan Kumar Dahal, Tribhuvan University

Secretariat: Dr. Kamala Kant Acharya, Tribhuvan University

Treasurer: Mr. Laxman Subedi, Nepal Geological Society

Member

- Mr. Achyut Koirala, Nepal Geological Society
- Mr. Ajab Singh Mahara, Nepal Electricity Authority
- Dr. Ananta Prasad Gajurel, Department of Geology, Tri-Chandra Campus
- Dr. Ashok Sigdel, Department of Geology, Tri-Chandra Campus
- Mr. Bala Ram Upadhayay, executive member, Nepal Geological Society
- Mr. Basanta Devkota, Nepal Geological Society
- Dr. Basanta Raj Adhikari, IoE, Tribhuvan University, Nepal
- Mr. Churna Bahadur Wali, Ministry of Irrigation
- Dr. Desh Raj Sonyok, USA
- Mr. Dev Kumar Shyangbo, executive member, Nepal Geological Society
- Mr. Devi Nath Subedi, Nepal Geological Society
- Mr. Dharma Raj Khadka, Department of Mines and Geology, Nepal
- Dr. Dibya Ratna Kansakar, Nepal Geological Society
- Mr. Dilendra Pathak, Nepal Geological Society
- Mr. Dilip Sadaula, Ministry of Energy
- Mr. Dinesh Napit, Department of Mines and Geology
- Mr. Dipendra Laudari, Department of Irrigation
- Dr. Ganesh Tripathi, Vice-president, Nepal Geological Society
- Mr. Govinda Sharma Pokharel, Nepal Geological Society
- Mr. Hari Ghimire, Nepal Geological Society
- Ms. Indira Shiwakoti, executive member, Nepal Geological Society
- Ms. Kabita Karki, Nepal Geological Society
- Mr. Keshav Rijal, Department of Irrigation
- Mr. Krishna Kumar Shrestha, Nepal Electricity Authority
- Mr. Krishna Upadhyaya, Department of Irrigation
- Mr. Kumud Raj Kafle, Kathmandu University, Nepal
- Mr. Lila Nath Rimal, Nepal Geological Society
- Mr. Lokendra Pandey, executive member, Nepal Geological Society
- Mr. Madan Ratna Manandhar, Tribhuvan University, Nepal
- Mrs. Monika Jha, Department of Mines and Geology, Nepal
- Mr. Moti Bahadur Kunwar, Nepal Geological Society
- Dr. Moti Lal Rijal, Tribhuvan University, Nepal

- Mr. Mukunda Raj Poudel, Department of Geology, Tri-Chandra Campus
- Mr. Narayan Adhikari, executive member, Nepal Geological Society
- Dr. Naresh Kazi Tamrakar, Central Department of Geology, Tribhuvan University, Nepal
- Mr. Nir Shakya, Nepal Geological Society
- Dr. Pitamber Gautam, Nepal Geological Society
- Mr. Prakash Chandra Ghimire, IoE, Tribhuvan University
- Dr. Prem Bahadur Thapa (Immediate Past Secretariat of IAEG Conference) Tribhuvan University, Nepal
- Mr. Rabindra Dhakal, executive member, Nepal Geological Society
- Mr. Rajendra Neupane, Department of Irrigatiion
- Mr. Rajendra Prasad Khanal, Department of Mines and Geology
- Mr. Ram Hari Sharma, Nepal Geological Society
- Mr. Ram Prasad Ghimire, Department of Mines and Geology
- Mr. Roshan Raj Bhattarai, Nepal Geology Society
- Mr. Sagar Kumar Rai, Ministry of Irrigation
- Mr. San Mukesh Amatya, Nepal Geological Society
- Mr. Sandeep Saha, Nepal Geological Society
- Mrs. Shoba Singh, Department of Mines and Geology
- Mr. Shyam K.C., Nepal Geological Society
- Mr. Sobit Thapalia, Nepal Geological Society
- Dr. Som Nath Sapkota, Department of Mines and Geology
- Mr. Subash Chandra Sunuwar, Nepal Geological Society
- Dr. Subodh Dhakal, Tribhuvan University, Nepal
- Mr. Sudhir Rajaure, Department of Mines and Geology
- Ms. Sunu Dawadi, executive member, Nepal Geological Society
- Mr. Surendra Maharjan, Joint-secretary, Nepal Geological Society
- Mr. Suresh Raj Upreti, Nepal Hydrogeological Association
- Ms. Sushmita Bhandari, Nepal Geological Society
- Dr. Tej Prasad Gautam, USA
- Mr. Tika Ram Paudel, Nepal Electricity Authority, Nepal
- Tuk Lal Adhikari, Nepal Geotechnical Society, Nepal
- Dr. Upendra Baral, China

Advisory Committee

- Mr. Achyuta Nanda Bhandari, Nepal Landslide Society
- Dr. Amod Mani Dixit, National Society for Earthquake Technology
- Mr. Bharat Mani Jnawali, Nepal Geological Society
- Prof. Dr. Bishal Nath Upreti, Nepal Academy of Science and Technology
- Dr. Dinesh Pathak, Tribhuvan University, Nepal
- Mr. Gopal Singh Thapa, Nepal Geological Society
- Mr. Jagadishwor Nath Shrestha, Nepal Geological Society
- Mr. Jagat Kumar Bhusal, Society of Hydrologist and Meteorologist
- Prof. Dr. Jibaraj Pokharel, Nepal Academy of Science and Technology
- Mr. Krishna Prasad Kaphle, Nepal Geological Society
- Prof. Dr. Lalu Prasad Paudel, Central Department of Geology, TU
- Prof. Dr. Megh Raj Dhital, Nepal Geological Society
- Mr. N.D. Maskey, Nepal Geological Society
- Mr. N.D. Maskey, Nepal Geological Society
- Mr. N.B. Kayastha, Nepal Geological Society
- Prof. Dr. Praksah Chadra Adhikary, Central Department of Geology, TU
- Mr. Pratap Singh Tater, Nepal Geological Society
- Prof. Dr. Ram Bahadur Sah, Nepal Geological Society
- Dr. Ramesh Man Tuladhar, Nepal Geological Society
- Mr. Ramesh Kumar Aryal, Nepal Geological Society
- Dr. Ramesh Prasad Basyal, Nepal Geological Society
- Prof. Dr. Suresh Das Shrestha, Central Department of Geology, TU
- Prof. Dr. Tara Nidhi Bhattarai, Department of Geology, Tri-Chandra Campus
- Prof. Dr. Tirtha Raj Khaniya, Tribhuvan University, Nepal
- Mr. Uttambol Shrestha, Nepal Geological Society
- Mr. V. Singh Chhetri, Nepal Geological Society
- Prof. Dr. Vishnu Dangol, Nepal Geological Society

International Advisory Members

Acknowledgements

Nepal Geological Society (NGS) is pleased to host the 11th Asian Regional Conference (ARC-11) of the International Association for Engineering Geology and the Environment (IAEG) in Kathmandu, Nepal on 28-30 November 2017. Founded in 1980, Nepal Geological Society (NGS) is a professional geoscientific organization with over 850 members and nearly one-third of them are international scientists. The Society is the National Group Member of International Association for Engineering Geology and the Environment (IAEG) and was a member of Nepal National Committee on International Decade for Natural Disaster Reduction (IDNDR) to led the IDNDR activities in Nepal for a decade. The Society was honored with: the 1998 United Nations Sasakawa Disaster Prevention Award Certificate of Merit in appreciation for its contribution to disaster prevention, mitigation and preparedness and Science and Technology Promotion Award from Nepal Academy of Science and Technology (NAST) in recognition of its contribution in the research and promotion of Geoscience.

The Nepal Geological Society also has a long history of affiliation with the IAEG and is assisting it by conducting various conferences and meetings, including the IAEG international symposium in 1999 and IAEG conference in 2005. The 1999 and 2005 events were attended by 419 and 209 geoscientists from 34 and 22 countries, respectively. This series of international conference has been an instrumental forum for the advancement of Engineering Geology in Asia. Geoscientists and engineers around the globe have contributed and benefited from each other from the Asian Regional Conferences of IAEG in the past. The main theme of the ARC-11 is **"Engineering Geology for Geodisaster Management"**, and it encompasses more than twenty different sub-themes, including *The 2015 Gorkha Earthquake; Engineering Geology of Landslides; Engineering Geology of Landslides-Monitoring and Early Warning System; Engineering Geology of Landslides -Hazard and Susceptibility; Landslide Disasters and Landslide Mitigation; Engineering Geology of Landslides - Earthquake Induced Landslide; Engineering Geology of Landslides- Rainfall induced Landslides and Debris Flow; Response and Reaction of Earth Materials to natural Phenomena; Foundation, Tunneling, Underground geology and Groundwater; Engineering Geology in Sustainable Development and urban Planning; Geohazards in Asia; Rockfall Hazard and its Mitigation; Engineering Geology and Geodisaster Management; Neotectonics and Geohazard Management; Engineering Geology and Geodisaster Management etc.* The main objectives of the Conference are to exchange expertise, experiences and knowledge for building effective cooperation among the geoscientists from all over the world, and is expected to help fill the knowledge gap in engineering geological issues in the time of reconstruction and recovery from the 2015-Gorkha earthquake and development of infrastructures in Nepal.

This volume contains 248 abstracts of scientists from 29 different countries comprising Australia, Austria, Bangladesh, Bhutan, Bulgaria, Canada, China, France, Germany, Greece, Hongkong, India, Indonesia, Italy, Japan, Malaysia, Nepal, New Zealand, Norway, Philippines, Portugal, Russia, Singapore, South Africa, South Korea, Taiwan, Turkey, United Kingdom and United States of America. The papers are categorized as Key Note presentations (12), Oral presentations (155), Poster presentations (70), Invited lectures (4), Special lecture (1) and arranged in 25 technical sessions with four parallel sessions. In addition, the Conference has pre-and-post -conference excursions in different parts of Nepal. About 400 participants are expected to attend the Conference.

We extend our warmest welcome to the delegates of the Conference and look forward to hosting you in Kathmandu, Nepal. We anticipate an exciting week of scientific exchanges, renewing friendships and making new friends. We hope you will find the ARC-11 of the IAEG a memorable event and the Abstract Volume a useful collection.

The Nepal Geological Society and the Committees of the ARC-11 of the IAEG are grateful to the following organizations and individuals for their financial and other supports in various ways to organize this international scientific event. The NGS is very much thankful to the IAEG for providing this opportunity to host the ARC-11 in Kathmandu, Nepal.

National Planning Commission, Government of Nepal
Department of Mines and Geology, Nepal
Department of Irrigation, Nepal
President Chure-Terai-Madhesh Conservation Development Board, Nepal
Nepal Academy of Science and Technology (NAST), Nepal
Department of Geology, Tri-Chandra Campus, Tribhuvan University, Nepal
Central Department of Geology, Tribhuvan University, Nepal
International Centre for Integrated Mountain Development (ICIMOD), Nepal
Nepal Electricity Authority, Nepal

International Consortium on Geo-disaster Reduction
Trumer Schutzbauten, Austria
Geotech Solutions International, Nepal
Kumonos Corporation, Japan
OYO Corporation, Japan
Earth Scanning Association, Japan
Maruti Cements Pvt. Ltd., Nepal
Sonapur Cements Pvt. Ltd., Nepal
Nigale Cement Pvt. Ltd., Nepal
Kanchan Quarries, Nepal
Kepy Cement Pvt. Ltd., Nepal
Bhardeu Cements Pvt. Ltd., Nepal
Shakti Mineral Pvt. Ltd., Nepal
Palpa Cements Pvt. Ltd., Nepal
Sidhartha Minerals Pvt. Ltd., Nepal
Sarbottam Cements Pvt. Ltd., Nepal
Shivam Cements Pvt. Ltd., Nepal
Cosmos Cements Pvt. Ltd Nepal
CG Cements Pvt. Ltd., Nepal
Shubhashree Agni Cement Udhyog Pvt. Ltd., Nepal
ICGS Pvt. Ltd., Nepal
BDA Nepal Pvt. Ltd., Nepal
Nissaku Co. (Nepal) Pvt. Ltd., Nepal
Subham Khanij Udhyog Pvt. Ltd & Samrat Cements Pvt. Ltd., Dang, Nepal
Geo Mining and Engineering Consultancy, Hetauda, Nepal
Arghakhanchi Cement Udhyog Pvt. Ltd., Nepal
Center for Disaster Management lnformatics Research, Ehime University
Faculty of Engineering, Kagawa University, Japan
Japan Society of Engineering Geology
Indian Society of Engineering Geology
The 36th International Geological Congress Secretariat, India
National Society for Earthquake Technology-Nepal
Nepal Engineers' Association (NEA)
Nepal Tunneling Association Nepal Hydropower Association
Nepal Landslide Society
Himalayan Landslide Society
Nepal Hydrogeological Association
Society of Hydrologists and Meteorologists
Annapurna Quarry, Tripureshwor, Kathmandu, Nepal
BDA Nepal Pvt. Ltd., Kathmandu, Nepal
United Cement Pvt. Ltd., Dillibazar, Kathmandu, Nepal
Albelo, Multi Trading Pvt. Ltd., Jawalakhel, Lalitpur
Riddhi Siddhi Cement Pvt. Ltd. Teku, Kathmandu
Smart Earth Work Engineering Consultancy Pvt. Ltd., Kathmandu

We are grateful to the members of Nepal Geological Society and IAEG, and various organizations and individuals who provided generous supports for successful organization of the ARC-11 of the IAEG in Kathmandu, Nepal.

The Nepal Geological Society and
The Organizing and Advisory Committees, ARC-11 of the IAEG

Contents

The 2016 Hans-Cloos Lecture

Keynote Lectures

Engineering Geology of Landslide

Neotectonics

Geohazards in Asia

Engineering Geology in sustainable development and urban planning

Foundation, underground geology and groundwater, and Tunneling

New technology

2015-Gorkha Earthquake

Marine Engineering Geology and related geohazards

Engineering geology of mines and quarry sites, and Geoethics in Engineering Geology and georisk reduction

Engineering geology for disaster risk reduction

Case studies for geohazard management

Rockfall hazard and its mitigation, and Other geohazards and hazard management

Others – related to engineering geology and geodisaster management

Yong Engineering Geologist Event

The 2016 Hans-Cloos Lecture of IAEG

Geo-engineering aspects on the structural stability and protection of historical man-made rock structures: An overview of Cappadocia Region (Turkey) in the UNESCO's World Heritage List

***Reşat Ulusay[1], and Ömer Aydan[2]**

[1]*Applied Geology Division, Department of Geological Engineering, Hacettepe University, Ankara, Turkey*
[2]*Department of Civil Engineering and Architecture, University of the Ryukyus, Okinawa, Japan*
**Corresponding author: resat@hacettepe.edu.tr*

Underground space has long been used through the history for the purposes of human accommodation, religious ceremony, protection from climatic conditions, defence, food storage etc. by humankind. There are a number of man-made underground rock structures in different areas all over the world which are also called "rupestrian settlements". Although some of them preserved their structural integrity, some of them have been mainly affected by weathering in different rates, natural hazards such as earthquakes, volcanic activities and landslides, and human activities. These effects may cause damage to these structures, their partial or total collapse and their failure if they are located next to steep cliffs, their erosion and even some have been completely destroyed and no longer exist. Therefore, both protection of their structural stability and minimizing the effects of internal and external factors on them have vital importance for all nations. Today the interest to utilization of underground space is still continuing. Besides assessment of the above mentioned issues is a complex endeavour, requiring expertise from the sciences of archaeology, architecture, conservation and geo-engineering such as engineering geology, rock mechanics and rock engineering.

The Cappadocia region in Turkey is one of the typical examples of these settlements. The Cappadocia region of Turkey is a typical example for rupestrian settlements and one of the sites in the world included in the World Heritage List by UNESCO in 1985. In this region, there are historical churches, dwellings, monasteries, cave houses, semi-underground (cliff) settlements and underground cities carved in soft tuffs which are still survive, and modern man-made cavities used for multi-purposes. Easy carving and thermal isolation properties of the soft Cappadocian tuffs have been the main reasons for the extensive multi-purpose underground use in the region from the past to the present. In addition, short- and long-term behaviours of these rock-hewn structures and the surrounding soft tuffs are also important data source in terms of underground geo-engineering.

The main goals of this paper are to point out the importance of engineering geology and its harmonization with rock mechanics and rock engineering in the assessments of short- and long-term mechanical behaviour of the host rocks, stability of rock-hewn structures and geo-engineering problems and environmental conditions associated with the historical rock-hewn structures with prime emphasize on the Cappadocia region. In addition, some cases selected from the Cappadocia region are also briefly discussed for highlighting the role of geo-engineering aspects on the stability and integrity of the historical rock-hewn structures and possible measures of their protection and mitigation are also given.

Engineering geological approaches adopted in reconstruction and relocation of the damaged settlements in the aftermath of 2015 Gorkha Earthquake

***Tara Nidhi Bhattarai[1], Stephen Richard Revill[2], and Kamal Ghimire[3]**

[1]*Department of Geology, Tri-Chandra Campus, Tribhuvan University, Kathmandu, Nepal*
[2]*Technical Advisor, Nepal Operations Center (NPOC), Kathmandu, Nepal*
[3] *National Reconstruction Authority, Land Management and Geological Study Section, Kathmandu, Nepal*
**Corresponding E-mail: tnbhattarai@wlink.com.np*

The Mw 7.8 Gorkha Earthquake occurred on 25 April 2015 and its subsequent aftershocks resulted in landslides, rock falls, ground ruptures, and liquefaction which severely damaged hundreds of settlements across the 31 most affected districts of Nepal. Based on rapid geological assessments, and reports from respective district disaster management committees, the Government declared 475 villages as the most vulnerable communities which needed to be shifted to safer sites at the earliest possible. But, as time passed and the subsequent monsoon did not trigger as many landslides as expected and initially feared, people started to return to their own land to reconstruct their homes. Meanwhile, the National Reconstruction Authority (NRA) was established on 20 December 2015 to handle all the earthquake reconstruction issues. Soon after its establishment, the NRA issued a public notice advising people not to start any reconstruction at the 475 vulnerable settlements. This situation created a tremendous pressure on NRA to justify its decision on the basis of scientific information, which was lacking at that time.

A Technical Committee, coordinated by a member of the NRA Steering Committee, was then formed to identify which government department had the mandate to cover the geotechnical investigation of the settlements, develop technical guidelines required for the investigation, and classify the vulnerable communities into one of three categories; namely Category-I (sites having geo-hazards which can be managed by communities themselves), Category-II (sites having geo-hazards which can be managed by applying appropriate engineering countermeasures for which government support is required), and Category-III (sites having geo-hazards which are extremely difficult to control or economically not feasible. Settlements belonging to this Category need to be relocated to safer site either entirely or in part).

The committee held several meetings with the officials of concerned government departments and representatives from professional societies. It also reviewed the mandates of the Department of Mines and Geology, the Department of Soil Conservation and Watershed Management, and the Department of Water Induced Disaster Management. Additionally, it also reviewed the existing methods of investigating geo-hazards and associated disasters.

The committee formulated field investigation guidelines considering geological, geomorphological, engineering geological, geotechnical and pertinent social parameters as guiding factors and recommended that the assessments be undertaken by teams led by a geologist with experts of water induced disaster management and a watershed management expert as members. The committee developed a technical training course to the professionals hired to undertake the survey before being deployed to the field. Moreover, the committee also recommended NRA to investigate the vulnerable sites under its own leadership.

Out of the 730 settlements investigated to date, 327 settlements were classified as Category- I, 213 as Category-II and 190 as Category- III. A further 200 settlements are still being investigated with the aim of completing the survey by the end of 2017.

A major role for engineering geologists and geotechnical engineers internationally - help produce resiliency plans for major hazards with an example from Oregon, USA

Department of Geology, Portland State University, Portland, Oregon P.O. Box 751, USA 97207

Scott F. Burns

E-mail: burnss@pdx.edu

Major geological hazards are found around the world and affect populations each year. Major hazards are earthquakes, floods, landslides, volcanic eruptions, tsunamis, and hurricanes (flooding). We, as engineering geologists and civil engineers, must work to reduce the effects of these hazards on the lives of humans and the infrastructure we live in. Each area of the world has its own set of hazards that dominate that environment. We must first study these hazards and understand their processes and the factors that affect them. Then, we must put together a resilience plan for the community working with emergency managers and local politicians. Such a plan defines the local hazards, the severity of the types of hazards, the vulnerability to those hazards, and then concludes with ways of how to reduce vulnerability and therefore loss of property and loss of life.

I have been involved in preparing the resilience plan for my state of Oregon in the United States mainly for our biggest hazard, a subduction zone earthquake (also called a megathrust). These are the biggest earthquakes in the world with magnitudes over 9.0. We live on the Cascadia Subduction Zone. I will explain how we put together the study and then how we put it into action with the population of Oregon through talks and outreach and changes laws.

Gravitational slope deformations that precede catastrophic landslides triggered by rainstorms and earthquakes

***Masahiro Chigira, and Noriyuki Arai**

Disaster Prevention Research Institute, Kyoto University, Japan
**Corresponding author: chigira@slope.dpri.kyoto-u.ac.jp*

Earthquake-induced or rain-induced catastrophic landslides cause enormous disaster because of their suddenness, large volume and high mobility. Their potential sites, therefore, must be predicted, but its methodology is not established yet. We know that those catastrophic landslides are mostly preceded by gravitational slope deformation, which can be a clue for the site prediction. Here we report characteristic features and internal structures of gravitational slope deformations that precede rain-induced or earthquake-induced catastrophic landslides from case histories.

Gravitational slope deformation forms many brittle open fractures, which are the groundwater pathways so pore pressure build up does not likely occur. However, our recent experiences of gigantic rain-induced catastrophic landslides in accretionary complexes suggest that they had a wide crush zone with gouge at their base (Arai and Chigira, 2015; Chigira, 2009), which seals fractures and prohibits water leakage from the deformed rock mass. 2009 Shiaolin landslide in Taiwan by typhoon Morakot was also bounded by a fault as well as bedding plane (Tsou et al., 2011). Those landslides with a sliding surface along a crush zone were preceded by gravitational slope deformation with a sliding along the crush zone and appeared as small scarps along their future crowns.

Earthquake-induced gigantic landslides, on the other hand, have somehow different geological structures of preceding gravitational deformation because it is induced by shaking rather than pore pressure build up even though preceding rainfalls have some effects on their occurrence. Typical gravitational slope deformations preceding earthquake-induced landslide are flexural toppling, buckling, and sliding of undercut slopes (Chigira, 2014). Flexural toppling is common in slate with well-developed slaty cleavage; if it contains rigid, massive rocks in higher elevations, the toppled rock mass may be more susceptible to shaking than homogeneous rock mass. Buckling of parallel or underdip cataclinal slopes forms very unstable slopes; typical landslides of this type were Chiu-feng-erh-shan landslide by 1999 Chi-Chi earthquake Taiwan (Wang et al., 2003) and Qingping landslides by 2008 Wenchuan earthquake (Fig. 1; Chigira, 2014). Another type of gravitational deformations that precedes catastrophic failure during earthquakes occurs on a buttressed slope like the Madison landslide by the 1959 Hebgen Lake earthquake in the USA.

REFERENCES

Arai, N., and Chigira, M., 2015, Rain-induced rock avalanches with a sliding surface along an out-of-sequence thrust. 10th IAEG Asian regional conference, Kyoto, TP1-17, 6p.

Chigira, M., 2014, Geological and geomorphological features of deep-seated catastrophic landslides in tectonically active regions of Asia and implications for hazard mapping. Episodes, v. 37, pp. 284–294.

Tsou, C.Y., Feng, Z.Y., and Chigira, M., 2011, Catastrophic landslide induced by Typhoon Morakot, Shiaolin, Taiwan. Geomorphology, v. 127, pp. 166–178.

Wang, W.N., Furuya, T., and Chigira, M., 2003, Geomorphological Precursors of the Chiu-fen-erh-shan Landslide Triggered by the Chi-chi Earthquake in Central Taiwan. Engineering Geology, v. 69, pp. 1–13.

Chigira, M., 2009, September 2005 rain-induced catastrophic rockslides on slopes affected by deep-seated gravitational deformations, Kyushu, southern Japan. Engineering Geology, v. 108, pp. 1–15.

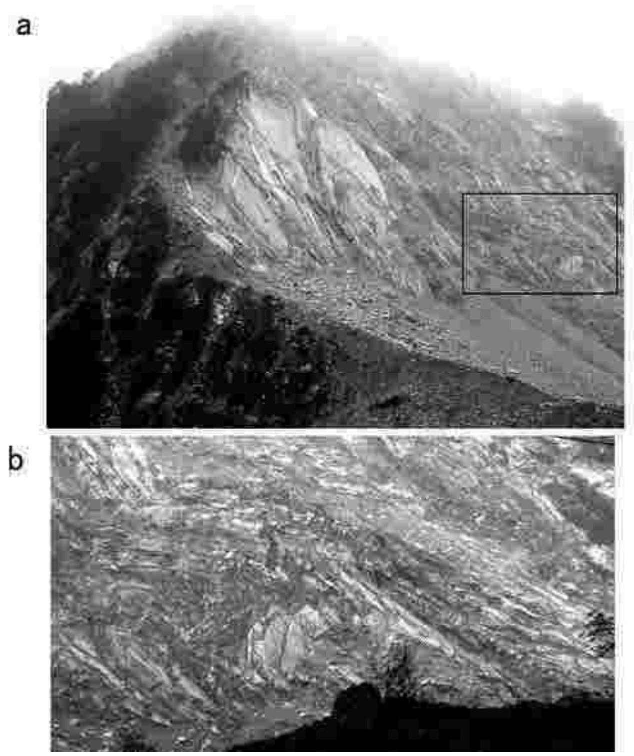


Fig. 1, Qingping landslide induced by the 2009 Wenchuan earthquake (Chigira, 2014): (a) overview and (b) buckle fold that remained behind the landslide scar

Managing geological situations at hydropower projects in Himalayas

Gopal Dhawan

Mineral Exploration Corporation Ltd., Seminary Hills, Nagpur, Maharashtra, India
E-mail: gdnoida@gmail.com

India has a vast hydro power potential of around 1,48,700 MW, a major part of which lies in the Himalayan region. However, in spite of high demand and huge available potential, the hydro power industry in the country has not yet progressed with desired speed due to various constraints, which cause delay in completion of the projects resulting in time and cost overrun. Among the various constraints responsible for inordinate delays in hydropower projects, uncertain geological condition is perhaps the most talked about reason. Often the time and cost overrun in hydropower project is attributed to “geological uncertainty" which refers to a sudden occurrence of extraordinary or adverse geological conditions during excavation of underground/surface structures, which were not anticipated at the time of investigation of the project.

In India, though several hydropower projects have already been constructed in Himalayas, it is always a challenging task due to complex geological and tectonic conditions. Moreover, extremely rugged, densely forested, and inaccessible topography delimit detailed investigation resulting inaccurate prognosis and in turn unexpected occurrence of geological problems like foundation problem in dams, stability problem in high cut slopes, unprecedented problems in tunnels and underground caverns like sudden ingress of water, interception of shear/fault zones resulting cavity/chimney formation, high stress conditions resulting bursting and squeezing, high temperature conditions, emission of noxious gases, etc.

Successful identification of risks during investigation, imbibing the geological risks in the contract by preparing a Geotechnical Baseline Report (GBR), assessment and successful management of risks by meticulous construction practices, overruling the unknown-unknown conditions during underground excavation by carrying out ahead of the face investigations are some of the other important practices to minimize the geological risks. Moreover, proper documentation of the lessons learned from the geological issues encountered in any project and the mitigation measures adopted to resolve the same is highly useful for formulating future projects in similar geological conditions to avoid geological complexities. Few practices if followed religiously, can result in minimizing geological issues in hydropower projects to considerable extent and can contribute significantly in rejuvenating the glory of hydropower projects in India. This keynote address shares some idea about the way forward towards effective management of geological situations in Himalayan hydropower projects with few case studies where these adverse geological conditions have been tackled efficiently based on proper co-ordination between engineers and geologists.

Paleoseismic studies of the Gatún, Limón, and Pedro Miguel faults for seismic hazard input to the Panama canal expansion in Central America

Eldon Gath

Earth Consultants International, Santa Ana, California USA
E-mail:gath@earthconsultants.com

As part of the geologic hazard investigation for the Panamá canal expansion project's design studies, we completed detailed paleoseismic investigations of the principal Gatún, Limón, Pedro Miguel faults, as well as several other faults in Central Panama. Tectonic- geomorphic mapping interpreted the fault traces, field reconnaissance identified potential investigation sites, trenching exposed the faults, and detailed geologic logging helped to quantify the fault's slip rates, recurrence intervals, and kinematic displacements. On all three of the primary faults we were able to identify and date the last three surface-rupturing earthquakes plus directly measure their slip displacements. The Gatún fault was shown to be dominantly left-lateral strike slip at 6–9 mm/yr, with three 0.75 m offsets in the last 500 years; the MRE being likely AD1848. The Limón fault was shown to be right-lateral strike slip at 4-6 mm/yr, with at least three offsets in the last 1600 years. The MRE was a 1.2 m displacement likely in AD1873, while the penultimate event was a 3 m event in AD1621. The Pedro Miguel fault was demonstrated to be a right-lateral strike slip fault at 4–6 mm/yr, with three events in the last 1500 years, and the MRE a 3 m displacement that occurred in AD1621 in a rupture that included the Limon fault. These studies provided geologically validated data directly into the seismic hazard calculations for the project's structural design. This talk will explore the tectonic-geomorphology of the fault zones, illustrate the process of conducting detailed paleoseismic studies of the strike slip faults, and conclude with implications for the seismic hazard of the Panama Canal and Panama City.

Challenges for operational forecasting and early warning of rainfall induced landslides

Fausto Guzzetti

Consiglio Nazionale delle Ricerche, Istituto di Ricerca per la Protezione Idrogeologica,
via della Madonna Alta 126, 06128 Perugia, Italy
E-mail: F.Guzzetti@irpi.cnr.it

In many areas of the world, landslides occur every year, claiming lives and producing severe economic and environmental damage. Many of the landslides with human or economic consequences are the result of intense or prolonged rainfall. For this reason, in many areas the timely forecast of rainfall-induced landslides is of both scientific interest and social relevance. In the recent years, there has been a mounting interest and an increasing demand for operational landslide forecasting, and for associated landslide early warning systems. Despite the relevance of the problem and the increasing demand, only a relatively few systems have been designed, and are currently operated. Inspection of the limited literature on operational landslide forecasting and on the associated early warning systems, reveals that common criteria and standards for the design, the implementation, the operation, and the evaluation of the performances of the systems, are lacking. This limits the possibility to compare and to evaluate the systems critically, to identify their inherent strengths and weaknesses and, finally, to improve the performance of the systems. Lack of common criteria and of established standards can also limit the credibility of the systems, and consequently their usefulness and potential societal impact.

Landslides are known to be very diversified phenomena, and the information and the modelling tools used to attempt landslide forecasting vary largely, depending on the type and size of the landslides, the extent of the geographical area considered, and the timeframe and scopes of the forecasts. As a result, systems for landslide forecasting and early warning can be designed and implemented at several different geographical scales, from the local (site or slope specific) to the regional, or even national scale. The talk focuses on regional to national scale landslide forecasting systems, and specifically on operational systems based on empirical rainfall threshold models. Building on the experience gained in designing, implementing, and operating national and regional landslide forecasting systems in Italy, and on a preliminary review of the existing literature on regional landslide early warning systems, the talk discusses concepts, limitations and challenges inherent to the design of reliable forecasting and early warning systems for rainfall-triggered landslides, the evaluation of the performances of the systems, and on problems related to the use of the forecasts and the issuing of landslide warnings. Several of the typical elements of an operational landslide forecasting system are considered, including: (i) the rainfall and landslide information used to establish the threshold models, (ii) the methods and tools used to define the empirical rainfall thresholds, and their associated uncertainty, (iii) the quality (e.g., the temporal and spatial resolution) of the rainfall information used for operational forecasting, including rain gauge and radar measurements, satellite estimates, and quantitative weather forecasts, (iv) the ancillary information used to prepare the forecasts, including e.g., the terrain subdivisions and the landslide susceptibility zonations, (v) the criteria used to transform the forecasts into landslide warnings, and the methods used to communicate the warnings, and finally (vi) the criteria and strategies adopted to evaluate the performances of the systems, and to define minimum or optimal performance levels. In many areas of the world, landslides occur every year, claiming lives and producing severe economic and environmental damage. Many of the landslides with human or economic consequences are the result of intense or prolonged rainfall. For this reason, in many areas the timely forecast of rainfall-induced landslides is of both scientific interest and social relevance. In the recent years, there has been a mounting interest and an increasing demand for operational landslide forecasting, and for associated landslide early warning systems. Despite the relevance of the problem and the increasing demand, only a relatively few systems have been designed, and are currently operated. Inspection of the limited literature on operational landslide forecasting and on the associated early warning systems, reveals that common criteria and standards for the design, the implementation, the operation, and the evaluation of the performances of the systems, are lacking. This limits the possibility to compare and to evaluate the systems critically, to identify their inherent strengths and weaknesses and, finally, to improve the performance of the systems. Lack of common criteria and of established standards can also limit the credibility of the systems, and consequently their usefulness and potential societal impact.

Engineering geology in active mountain belts

Shuichi Hasegawa

Department of Safety System Construction Engineering, Kagawa University, Takamatsu, Japan
E-mail: hasegawa@eng.kagawa-u.ac.jp

The Himalaya is characterized by the highest mountain range of over 8000 m in height which has been formed by the collision of India and Eurasia plates. Japan is located where the Pacific and Philippine Sea plates subduct under the Eurasian plate. Shikoku Island is located at southwest part of Japan, where the Eurasian plate is subducted by the Philippine Sea plate.

Geological background of slope disasters between Nepal and Shikoku, southwest Japan is very similar. Nepal and Shikoku has similar topographical arrangement. The uplift of the Higher Himalaya and Shikoku Range is closely related to the intrusion of the Miocene granitic rocks. The batholith of the Miocene granites has uplifted isostatically due to the buoyancy of relatively light granites. Although no Quaternary volcano is distributed in the Himalaya and Shikoku Mountain Range, hydrothermal activity due to the Miocene volcanism are recognized in both areas. The thermal source of hot springs and hydrothermal alteration of both areas are closely related to the Miocene volcanism. The Miocene hydrothermal alteration produced clay minerals in the bedrock as fault gouges or clay veins and became a geological factor of deep-seated landslides.

Big earthquakes are great threats to Nepal and Shikoku. In Shikoku, the Nankai Trough subduction mega-earthquakes have occurred in hundred-year intervals and the Median Tectonic Line (MTL) shallow mega-earthquakes have occurred in thousand-year intervals. Large-scale landslides which have provided gentle slopes for settlements in steep Shikoku Mountain Range were mainly triggered by MTL mega-earthquakes.

The Midland in Himalaya which consists of gentle hills between the steep Higher Himalaya and the steep Mahabharat Range were probably results of past giant landslides. Relatively slight damaged in the Midland during the 2015 Gorkha earthquake can be explained by the cushion of thick fractured and porous landslides masses which had formed more than one million years ago. Intermountain basins like Kathmandu Valley might have been formed from landslide-lakes by the ancient mega-landslides.

Therefore, I believe that experiences and lessons from the tunnel and express way construction practices in Shikoku Mountain Range is indispensable and our experiences will be highly useful for construction of fast track-roads in Nepal.

Seismotectonics and seismic hazard potential of Northwest Himalaya

Prabhas Pande

Geological Survey of India
E-mail: prabhaspande51@gmail.com

The 2400 km long Great Himalayan orogenic belt, confined between the lofty mountains of Nanga Parbat in the west and Namcha Barwa in the east, is embraced by the mighty Indus River at one end and the Brahmaputra River at the other. This south convex system of ranges occurring south of the Tibetan plateau includes in its fold the territories of Pakistan, India, Nepal, Bhutan and China. The Northwest segment of the Himalaya, constituting nearly 40% length of the mountain belt, lies between the Indus-Jhelum and Kali valleys. It maintains a general northwesterly trend except in its western terminal where the attitudes get abruptly acutely reversed.

The most spectacular feature of the Himalayan orogen is the Western Syntaxis. In the frontal part, this orogenic bend is reflected as the Jhelum re-entrant, flanked on either side by the Kashmir and Peshawar basins. The northern most tectonic discontinuity of the area is the Main Karakoram Thrust (MKT) that separates the Hindukush-Karakoram belt from the Island Arc of Kohistan. Towards south, the Main Mantle Thrust (MMT) separates the latter from the Peshawar and Kashmir basins. These two major discontinuities are considered to represent the earliest sutures of this complex tectonic domain. Southern most is the Main Boundary Thrust (MBT), which divides the main Himalayan package from the sedimentary sequence of the Frontal Fold Belt (FFB). The FFB along with Panjal thrust is involved in the Kashmir-Hazara Syntaxis that formed due to the interaction of three independently moving tectonic elements, viz, the Himalaya, the Indian Shield and the Salt Range. An integrated lithospheric model constrained on the basis of isostatic studies and seismic investigations reveals a crustal thickness of 60 km beneath the Karakoram-Pamir region, and suggest continental subduction from the Indian as well as the Eurasian sides, leading to the development of a complex compressional stress environment in a depth range of 80-180 km to 170-250 km. Further southeast, that is between the Kashmir and Kumaon Himalaya, the 300 km wide chain from north to south can distinctly be divided into Trans, Higher, Lesser and Sub Himalayan geomorphic entities, each being sandwiched between major structural discontinuities, namely Indus-Tsangpo Suture Zone (ISZ), Main Central Thrust (MCT), Main Boundary Thrust (MBT) and Main Frontal Thrust (MFT).

The Himalaya, which came into existence by the continued collision of the Indian plate with the soft underbelly of Eurasia in Miocene times, is still in a state of flux. It is estimated that the plate presently moves at the rate of 67 mm/year as a result of which the Tibetan plateau, presently under the influence of an extensional tectonics, continues to move upward, and the thrusting along the Himalayan southern front leads to the rise of the Himalaya by about 5 mm/year. The recent results of GPS measurements of crustal deformation across the Kashmir Himalaya suggest that the motion between the southern Tibet and India is almost north-south at the rate of 17±2 mm/year, which is partitioned between dextral motion of 5±2 mm/year in the Karakoram fault system and oblique motion of 13.6±1 mm/year in the Kashmir Himalayan frontal arc. The tectonic stresses operative in the Quaternary times have caused reactivation of several of the dislocation planes of the frontal belt at different places and at different times, the most recent one being the coseismic rupturing of the 85 km long Balakot fault consequent to the 2005 Muzaffarabad earthquake.

The Steady State and Evolutionary Seismotectonic Models of the Himalaya show that the subsequent generation thrusts like the MCT, MBT and HFT imbricate along the detachment plane, the zone of inflexion along which has been referred to as the ‘basement thrust front’. These models also suggest that the larger seismic events are located just south of the MCT trace and nucleate at depths of 15-20 km along the detachment surface. The pattern of seismic energy release in the contemporary times indicates that in the Garhwal-Kumaon Seismotectonic Blocks, the major strain release is towards the northern boundary of the Lesser Himalaya whereas it is more towards Lesser Himalaya’s southern boundary in the Kangra and Kashmir Blocks. The deep seated transverse discontinuities of the Himalaya, which could be the primordial structures of the peninsular mass, are important in two ways. Firstly, these form locales of major asperities wherever intersected by discontinuities paralleling the Himalayan trend, including the detachment plane. Secondly, the transverse faults constrain the boundaries of seismogenic blocks and so define their generating capabilities and hazard levels.

The seismicity data for the period from 1905 to 2007 in and around the Western Syntaxis shows occurrence of 949 seismic events of magnitude 4 and above. The earthquakes in the Kashmir-Hazara Syntaxis have been attributed to the activity along the detachment plane beneath the surface trace of the MBT. The seismicity of the Kohistan Arc lying on top of the Kohistan/Ladakh plutonic complex has yet to be assigned to any known seismogenic structure. The seismicity around the Nanga Parbat Syntaxis is clustered more in its western part along the active Raikhot fault and Diamer shear zone, whereas in the eastern part it is only of a diffused nature. The Kashmir, Kangra, Garhwal and Kumaon seismotectonic Blocks constitute domains of high seismicity prevailed upon by a compressional stress regime where the activity is mostly concentrated within the Lesser Himalayan crustal slice along the detachment surface. The Spiti-Kaurik Block of Northwest Himalaya is an exception for the reason that it is marked by extensional tectonics. The destructive seismic events of Northwest Himalaya include the 1803 and 1816 earthquakes of Upper Ganga valley of M6.5-7.0, 1885 Kashmir earthquake of M7.0, 1905 Kangra earthquake of M8.0, 1906 Sundarnagar earthquake of M 7.0, 1916 Dharchula earthquake of M7.5, 1945 Chamba earthquake of M6.5, 1980 Dharchula earthquake of M6.0, 1991 Uttarkashi earthquake of M6.6, 1999 Chamoli earthquake of M6.8 and 2005 Muzaffarabad earthquake of M7.6. In a probabilistic assessment of seismic hazard of Northwest India, peak ground acceleration values for a return period of 475 years were found varying from 0.15g in the Terai region to 0.35g in Kangra and Garhwal Seismotectonic Blocks (GSI-BRGM Report, 1995). The extensional block of Kaurik-Spiti in Himachal Pradesh showed the highest acceleration of 0.38g, whereas in the Kashmir, Kohistan and Peshawar Units, accelerations of 0.24g were computed. The Hindu Kush region gave accelerations of 0.33g.

The region of Northwest Himalaya is bestowed with bountiful rain/snowfall that feeds the numerous glaciers and rivers belonging to the Indus and Ganga basins, year after year. Hence, some of the major hydroelectric projects like Mangla, Tarbela, Bhakra, Pong, Ranjit Sagar, Salal, Tehri, Ramganga, etc. have come up in this segment of the Himalaya in the last five decades and many more, such as Pancheshwar (Indo-Nepal border), have been proposed. In the recent times, the construction activity in the Himalaya has increased manifold that has led to a phenomenal rise in the population density, particularly in the adjoining region of Indo-Gangetic plains. A scenario earthquake study carried out by the National Disaster Management Authority (NDMA, India), during 2012-13 reveals that if a hypothetical earthquake of magnitude 8.0 occurs somewhere around Mandi in Himachal Pradesh at dead of night, the human casualty figures could go as high as 900,000 because of the highly increased vulnerability of the built environment. This goes to show that the entire Northwest Himalaya, like rest of the mountain belt as well as the immediate surrounding regions, constitutes a domain of very high to high seismic hazard and, therefore, merits comprehensive understanding of the tectonic processes operative within the earth's interior, on the one hand, and adoption of safer ways to live in a seismotectonically unpredictable and surcharged environment, on the other.

Himalayan geological setting and status of engineering geological research and education in Nepal

Lalu Prasad Poudel

Central Department of Geology, Tribhuvan University, Kirtipur, Kathmandu, Nepal
E-mail: lalupaudel67@yahoo.com

Major intracrustal thrusts divide the Nepal Himalaya into four tectonic zones, i.e., Sub-Himalaya (Siwaliks), Lesser Himalaya, Higher Himalaya and Tethys Himalaya, from south to north, respectively. Each of these zones is geomorphologically distinct and shows contrasting lithostratigraphy and tectonic style. The Main Frontal Fault (MFT) marks the frontal tectonic boundary of the Himalayan range with the Indo-Gangetic Plain. The Siwaliks comprise about 6 km thick fluvial sedimentary rocks such as interbedded conglomerates, sandstones, and mudstones. They were deposited in the Himalayan foredeep basin between the Middle Miocene and early Pleistocene times. The northern boundary of the Siwaliks is the Main Boundary Thrust (MBT). It is followed in the north by the Lesser Himalayan fold-and-thrust belt comprising Late Precambrian-Early Paleozoic, low- and medium-grade metasedimentary rocks such as slate, phyllite, quartzite, metasandstone, marble, etc. The northern boundary of the Lesser Himalaya is the Main Central Thrust (MCT). It is followed in the north by the Higher Himalaya which is composed of about 10 km thick pelitic, psammitic and calcareous paragneisses, granitic orthogneisses and migmatites. The Higher Himalaya has overthrust the Lesser Himalaya along the Main Central Thrust (MCT) and form a nappe in the Kathmandu area and in several parts of Nepal. The northern boundary of the Higher Himalaya is the South Tibetan Detachment System (STDS). The Tethys Himalaya consists of about 10 km thick Cambrian to Eocene, shelf-sediments deposited on the northern margin of the Indian continent.

Active thrusts and shear zones with deep alteration and weathering, intense folding and fracturing of rocks, old landslide topography, karst landforms in carbonate terrains, soft and young rocks, lacustrine sediments, swelling clays and silts, steep topography with fragile rocks and sediments, high altitude mountains with fast-moving and melting glaciers, and glacial lakes dammed with ice and moraines are the major features creating adverse engineering geological condition in the Nepal Himalaya for infrastructure development and environmental management. Because of the above conditions Nepal is facing frequent natural disasters like landslide, earthquake, flood and GLOF every year. Engineering projects such as hydropower, roads, bridges, dams, canals, multi-storied buildings, etc. are facing problems like slope failure, ground subsidence and settlement, squeezing and caving in tunnels, underground drainages, raveling ground, etc.

Realizing the importance of the Engineering Geology in Nepal, Tribhuvan University introduced Engineering Geology subject (100 marks) in the M. Sc. Geology from the beginning of its master's course in 1976. The contents of the Engineering Geology were gradually increased. Tribhuvan University started Engineering Geology stream (500 marks) in M. Sc. Geology from the year 2000. In view of the need of trained manpower in the field of Engineering geology in the country, and having its wide range of scope internationally, the M. Sc. Engineering Geology Program has been established in 2014 and the first batch of students was enrolled in 2015. The aim of this course is to produce required manpower who can competently work in the field of Engineering Geology and capable of fulfilling the present demand of the industry and academia. Along with the new course of Engineering Geology, Geo-disaster Research Centre has been established at the Central Department of Geology to carry out research on geo-disaster in Nepal. Tribhuvan University also looks for and welcomes international students in M. Sc. Engineering Geology program and collaborative research in the geo-disaster.

Failure prediction of landslide dam and motion simulation of landslide

Fawu Wang

Department of Geoscience, Shimane University, Japan
E-mail: wang.fawu@gmail.com

Prediction is very important for disaster reduction. In this paper, two types of prediction will be introduced: the failure time prediction of landslide dam and the motion simulation of landslide when it occurs.

For landslide dam, there are three different types of failure mechanisms: overflowing, piping and sliding. Among them, landslide dam failure caused by piping is of highest danger, because it usually takes long time for piping phenomenon to make a sudden failure of a landslide dam. For the purpose to make time prediction on the landslide dam failure caused by piping, microtremor chain survey method is applied to detect the internal structure of landslide dam, and evaluate the situation of a landslide dam after piping for short or long period. When the landslide dam is in loose structure resulted from piping, self-potential survey method is applied to find the groundwater flowing path under the surface of a landslide dam. When the internal structure and groundwater situation of a landslide dam is clarified, it is necessary to find some apparent indicators for failure prediction. Through outdoor small scale landslide dam failure tests, we found that turbidity change of the water coming from the landslide dam, and the subsidence of the landslide dam crest (surface) can be used for this purpose.

For landslide motion, those travelling for long distance are always of strong impact. Using a landslide motion model by Sassa (1988), and adopting an apparent friction changing model by Wang and Sassa (2002), motion simulation of landslide can be made in high reliability. In this paper, the geological meaning of those models will be examined.

Multi-temporal interferometry and high resolution radar satellite data enable long-term slope monitoring and capturing of pre-failure signs of instability

***Janusz Wasowski[1], Fabio Bovenga[2], Raffaele Nutricato[3], Davide Oscar Nitti[3], and Maria Teresa Chiaradia[4]**

[1]Research Institute for Geo-hydrological Protection, National Research Council (IRPI-CNR), Bari, Italy
[2]Institute of Intelligent Systems for Automation, National Research Council (ISSIA-CNR), Bari, Italy
[3]Geophysical Applications Processing GAPsrl, c/o Department of Physics, Polytechnics/University of Bari, Italy
[4]Department of Physics, Polytechnics/University of Bari, Bari, Italy
**Corresponding author: j.wasowski@ba.irpi.cnr.it*

New high resolution optical and radar sensors and improved digital image processing techniques allow timely delivery of information that is sufficiently detailed (and cost-effective) for many practical engineering applications. For example, LiDAR and UAV-based remote sensing can provide very high (cm-dcm) spatial resolution imagery for producing detailed topographic maps and DEM. Furthermore, detailed measurements of ground and infrastructure deformations can be obtained using ground based interferometry (GB-InSAR) or exploiting satellite radar imagery and advanced multi-temporal interferometry (MTI) techniques like PSInSAR, SBAS (Wasowski and Bovenga, 2014a,b).

In this presentation, we focus on the new space-borne radar sensors, which offer great potential for multi-scale (regional to site-specific) ground deformation monitoring thanks to wide-area coverage (tens of thousands km^2), regular image acquisition schedule with increasing re-visit frequency (weekly to daily), and high measurement precision (mm). In particular, we demonstrate the potential of the new European Space Agency (ESA) satellite Sentinel-1 (S-1) for long-term slope monitoring and capturing of pre-failure signs of instability. This is done by using two case study examples and presenting MTI results obtained through the Persistent and Distributed Scatterers (PS/DS) processing capability of the SPINUA algorithm.

The first case regards a hilltop town in the Apennine Mts., Italy, whose stability is threatened by a large (~600 x 300 m^2), slow-moving deep landslide. The MTI results based on S-1 data from the period 2014-2016 revealed an accelerating trend with a nearly doubled velocity of the surface displacements with respect to those in the earlier period covered by the data provided by the older ERS and ENVISAT satellites. The higher frequency of S-1 acquisitions (about 30/year in this case) helped highlighting the non-linearity of the displacements within the faster movement phase, whose timing was consistent with the increase in landslide activity detected through subsurface inclinometer monitoring and field observations. The latter demonstrated that this faster movement phase coincided with (or was preceded by) a failure of the landslide toe.

The second case represents an example of a retrospective investigation of a huge (about 2.7 km long, several tens of m deep) landslide, which occurred in 2016 in an important open-cast coal mine in central Europe. The seemingly sudden failure disrupted the mine operations, destroyed mining machinery and resulted in high economic losses. In this case, we exploited over 60 S-1 images acquired since November 2014. Despite the presence of spatial gaps in information (due to intensive surface disturbance by mining operations), the MTI results provided a good overview of the ground instability/stability conditions in the mine area. Furthermore, it was shown that the 2016 slope failure was preceded by very slow (generally 1–3 cm/yr) creep-like deformations, already detectable in 2014. Although it would not have been simple to issue a short-term warning of the impending failure based on the displacement time series, the MTI results showed that the slope had been in the critical instability state some months prior to the landslide event. Furthermore, the spatio-temporal mapping of interferometric coherence changes indicated a sharp coherence loss in the last few weeks before the slope collapse.

The above examples demonstrate that by securing long-term, regular, high-frequency acquisitions all over the globe, the Sentinel-1 mission can promote a more effective use of MTI in slope instability hazard assessment. The availability of more frequent, wide-area measurements from space leads to improved landslide monitoring and opens new opportunities for slope failure forecasting efforts. Thanks to this and to ESA's open access policy for images, site-specific investigations relying on MTI are now more feasible (and cost-effective) also for non-scientific users.

REFERENCES

Wasowski J., and Bovenga F., 2014a, Investigating landslides and unstable slopes with satellite Multi Temporal Interferometry: Current issues and future perspectives, Engineering Geology, v. 174, pp. 103–138.

Wasowski J., and Bovenga F., 2014b, Remote Sensing of Landslide Motion with Emphasis on Satellite Multitemporal Interferometry Applications: An Overview. In T. Davies (Ed). Landslide Hazards, Risks and Disasters. pp. 345–403. Copyright © 2015 Elsevier Inc.

Statistic-Mechanical model of rock mass and its applications

Faquan Wu

Shaoxing University, Zhejiang 312000, China
E-mail: wufaquan@mail.igcas.ac.cn

A Statistic-Mechanical model will be proposed to describe the geometrical and mechanical behaviors of jointed rock mass, which includes its geological structure, deformation and strength. As its basis, the geometrical model is to describe the number of joint sets and the orientation, density and average opening and size of each set of joints. A stress-strain relationship is to provide the theoretical model for deformation analysis of rock mass, based on the geometrical model and fractural mechanical behavior. And the strength model will provide the calculation method and criterion of strength of rock mass.

As the applications of the theoretical models, the formulas for parameter calculation like whole spacing elastic modulus, Poisson's ratio and UCS of rock mass, and rock mass classification have been applied. Meanwhile, some practical examples will be illustrated from railway tunnels and high dam slopes.

Journal of Nepal Geological Society, 2017, Vol. 54 (Sp. Issue)

The impact of earthquake and monsoon induced Landslides on rural and remote transport infrastructure: a case study from Nepal

Michael R.Z. Whitworth

AECOM, Plumer House, Third Floor, East Wing, Tailyour Road, Plymouth, U.K. PL6 5DH

Transport and thus transport infrastructure is fundamental to economic growth and the delivery of basic services, including education and health care. Rural and Remote infrastructure, known as low volume roads are the primary transport routes in the rural parts of most low-income countries. These routes enable the access to basic services and economic and social opportunities. However, many of these low-income countries suffer from the impact of natural disasters, with more people killed by natural disasters in poor countries. Nepal is one such country, with the country ranked as the 18th poorest in the world, with on average over 1000 people killed annually from natural disasters, with over 250 deaths from floods and landslides (2000–2014), with 137 people killed by the Jure (Sunkoshi) Landslide in 2014. In the 2015 Gorkha Earthquake, 9000 people were killed with an estimated 10% killed by earthquake induced landslides (over 3500 landslides recorded).

This paper focuses on a series of earthquake induced landslides and the impacts of these landslides on vital rural access routes. The location of the study area lies 10 km east of the epicentre of the 2015 Earthquake, along a 10 km section of the Budhi Gandaki River between Lapu Besi and Khorla Besi, and the adjacent villages of Yamguan, Lapsibot and Machhakholagan. From interviews conducted with villagers 24 people (total population of between 350 and 500) were killed from landslides, with no reported deaths from the earthquake and associated building collapse. Along the 10 km stretch of river and covering an area of approximately 20 km^2, over 20 landslides were observed. These landslides were predominantly debris avalanches, channelised debris flow and rock falls, with source zones up to 400 m in length, and a source zone of 10,000’s m^2. The longest run out distance was up to 1 km. These landslides have had a significant impact, with several villages abandoned, including Machhakholagan and Khorla Besi. The Mansalu circuit, a popular trekking and vital transport route to the more mountainous regions in the north passes along the river valley. Several landslides were observed to have affected the network of tracks, including routes linking the east and west of the valley. These landslides not only hindered the immediate relief effort, but are likely to affect the long term recovery of the area. A Comparison is made between these landslides and the impacts of monsoon induced landslides along a 60km stretch of the Araniko Highway, a key route connecting Nepal and China that has been severely impacted by both monsoon and earthquake induced landslides including the Sunkoshi (Jury) landslide dam.

Experimental study on rock stability assessment with strength deterioration of slide surface

Yan DU[1], Mowen XIE[1], Hongke Song[1], Asim Farooq[1], Yujing JIANG[2], and Edward J. Williams[3]

[1]School of Civil Engineering, University of Science & Technology Beijing, China
[2]Graduate School of Engineering, Nagasaki University, Japan
[3]School of Civil Engineering, University of Michigan, United States

The interior instability of rocks, after an earthquake and heavy rainfall, is one of the main causes of rock failures. However, fundamental natural frequency can demonstrate the changes in physical and mechanical parameters and effect a qualitative and quantitative assessment of the safety of rocks. This study applied an experiment called Frozen-Thawing Test (FTT) in which the entire collapse process caused by strength degradation is simulated. The results show that the vibration amplitude in the end-stage of the failure process is higher than in the beginning; and the fundamental natural frequency decreases over time, from above 10 Hz at the beginning to below 5Hz at the end. The stability estimation of unstable rock by vibration properties in the experiment indicates that it can be a useful method to predict the strength regression and stability of unstable rocks.

Effect of weak plane orientation on rock slope stability

Yi-Ling Lin, Po-Tsun Yeh, and *Kuang-Tsung Chang

Department of Soil and Water Conservation, National Chung Hsing University, Taiwan
**Corresponding author: changkt@nchu.edu.tw*

Except the shallow landsides that are associated with soils, other slope stability problems are associated with rock. The hill slopes in Taiwan are mainly composed of sedimentary rocks and metamorphic rocks. The bedding planes of the sedimentary rocks and the cleavage of the slate are weak planes with good persistency. Various orientations of the weak planes have different effects on the stability of rock slopes. We study the effects of orientations of planar and wedge weak planes on slope stability, using the software PLAXIS 3D. Simple slope models with various weak plane conditions are simulated. The jointed rock model with overall Mohr-Coulomb failure criterion (Iso-JRMC) is used to take the weak planes into account. The results show that for planar weak planes conditions, the most unfavorable conditions appear when the weak planes and the slope dip to the same direction, and the dip angle of the weak planes coincides with that of the slope or is equal to 90 °. For wedge weak planes conditions, the most unfavorable conditions appear when the line of intersection of two sets of weak planes and the slope dip to the same direction, and the plunge of the line of intersection coincides with the dip of the slope or is equal to 90 ° . In particular, for wedge weak planes conditions, the higher the difference of the dip angles of the two sets of weak planes, the lower the safety factor of the slope obtained.

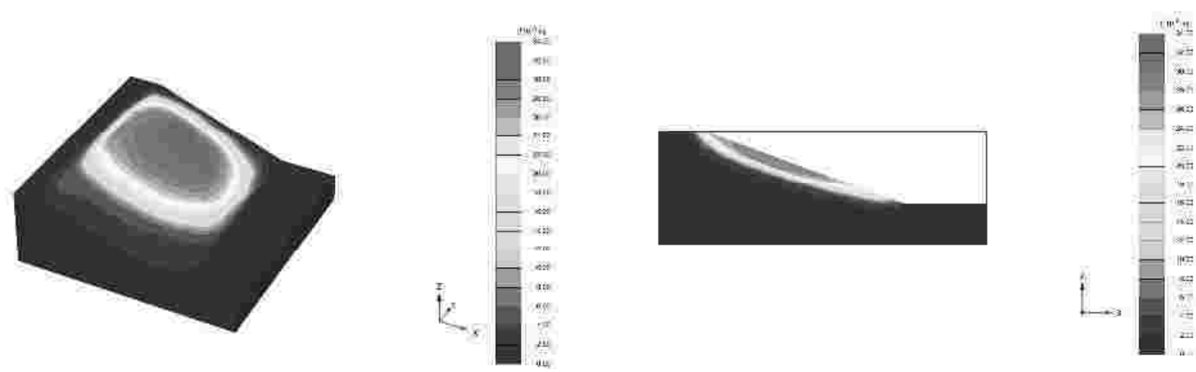


Fig. 1, A slope model with weak planes. The slope and the weak planes have the same angle of inclination, and the angle between their dip directions is 30 degrees. (a) failure condition (b) longitudinal profile

Probabilistic landslide hazard assessment of the Black Sea coastline of Russia

***Andrey Kazeev, German Postoev, and Ksenia Fedotova**

Sergeev Institute of Environmental geosciences RAS, Moscow, Russia
**Corresponding author: info@opolzni.ru*

Landslide hazard assessment of slopes in Sochi was made along the railway between the cities Tuapse and Adler (total length 103 km). The railway passes through the territory with active development of hazardous geological processes such as landslides, rock falls and debris-flows.

In recent years the intensification of landslide deformations occurred. For instance, during previous 10 years (1996–2005) 28 sudden deformations occurred due to slope processes, which caused interruptions in traffic. In the present decade (2006–2015), 72 deformations were recorded.

High landslide activity and economic loss demand pervasive investigations of engineering geological conditions of landslides development and causes of its intensification. Development of a protection strategy is also needed for minimizing negative consequences. Thus, the investigations of landslide situation along the railway “Tuapse–Adler” included the categorization of landslide sites by their hazard, with risk assessment based on numerical criteria.

Preliminary evaluation of landslide hazard for the railway was made via the analysis of archive engineering-geological data. Thirteen of 30 landslide sites (for about 13 km length) were selected including both active and inactive sites, reflecting the variety and peculiarities of landslide displacements on the slopes. Visual field observations of landslide slopes using drone “DJI Phantom 4” were fulfilled on the second stage of investigations on selected landslide sites (Fig. 1). High-resolution photographs of landslide circuses, landslide cracks, scarp walls, and specific vegetation were obtained via drone, which would have been impossible to obtain from the ground in conditions of dense tropical vegetation on slopes.

Possible approaches to the landslide activity and hazard assessment were analysed through slope stability analysis, geophysical monitoring, analysis of critical deformations and critical velocities of displacement, analysis of changes of conditions of development of a landslide during its displacement, and approaches of scoring to landslide hazard and risk assessment. As the result, the method of probabilistic estimation of landslide activity and landslide hazard has been proposed based on the determination and analysis of main factors, which influence on landslide displacements.

The assessment of landslide activity on sites was made with the usage of such factors as slope steepness, landslide thickness, the slope length, the direction of bedrock inclination, the slope relief, cracks on the slope and specific vegetation.

The investigation was based on the proposed method of determining the probabilistic assessment of landslide activity and hazard. The 13 studied landslide sites were ranked by the rate of activity as inactive, potentially active and active. The most active sites were used to identify the most hazardous sites. For assessment of landslide hazard the following factors were added: the involvement of railroad facilities by a landslide, landslide activity, thickness of landslide masses at the toe of the slope, the direction of the bedrock stratification, the conditions for the cirque extension, the position of the sliding surface relatively to the railway, and the involvement of bedrock into displacement.

As the result, the investigated sites of the railroad were divided into three classes: non-hazardous, potentially hazardous and hazardous.

Fig. 1, Landslide site in Sochi

The main causes and damages associated with the deadliest landslides during June-July, 2015 in the South-Eastern part of Bangladesh

***Animesh Talukder, and Anwar Saadat Mohammad Sayem**

Geological Survey of Bangladesh, Segunbagicha, Dhaka, Bangladesh
**Corresponding author: talukder_animesh@yahoo.com*

Bangladesh is highly vulnerable to several natural disasters and every year natural calamity upsets human's lives and livelihood here. Now-a-days among major disasters fatal landslide events are notable. During rainy season landslides become common in the hilly areas of South-Eastern part of Bangladesh. The landslides during June-July, 2015 in the mentioned area killed 20 people and made many people severely injured and homeless. A topographic sheet on scale 1:50,000 has been used for landslide investigation. GPS and a digital camera have been used to collect the geographic location and photos for documentation, respectively. The geological behaviors of the landslide materials and nature of failures for each landslide have been studied in detailed. Each landslide area was plotted on the existing geological map of Bangladesh to correlate with the local geology and geological structure of the area. Moreover, ten soil samples were collected from different locations for laboratory analysis.

In field investigation, it was observed that the geology of the investigated area mainly consisted of sandstone and shale. The results of Grain size analysis showed that the slope-forming materials consisted of mainly sand with clayey silt. From Atterberg limit tests, it was found that the soil type was inorganic silt. During heavy rainfall, sand material became saturated with high water content due to its permeable nature. Due to low plasticity of silt, it became saturated and started flowing. As a result, shear strength of these materials reduced and made the slope unstable. Fine clayey materials, which were produced by rock weathering, after interacting with water became lubricant, and were also responsible for slope failure. For mitigation measures, construction of retaining wall and proper drainage system, suitable afforestation, and development of Landslide Early Warning System are suggested. Besides, effective rehabilitation of the vulnerable dwellers, awareness building through education and strengthening the existing acts for protecting the hill slopes are also important.

Landslide susceptibility mapping along the road corridor from Bandeu to Barahabise, Araniko Highway, Sindhupalchowk District

***Anu Khadka [1], Subodh Dhakal [2], and Ajaya Bhakta Mathema [3]**

[1] *School of Environmental Science and Management, PU,Baneshwor*
[2] *Assistant Professor, Tri-Chandra Campus,TU, Ratnapark*
[3] *Associate Professor, School of Environmental Science and Management,PU, Baneshwor*
**Corresponding author: anukhadka16@gmail.com*

Landslide is one of the main natural hazards that occur frequently in the Nepal Himalaya causing huge loss of life and property every year especially during rainy season. Landslides occurred in the Sindhupalchowk District, Jure (2nd August, 2014), along the road corridor of Araniko Highway blocked Sunkoshi River resulting loss of 156 lives, damaged road section and huge property loss. Due to the weak geological condition, rapid developmental activities and other inherent natural conditions, Barhabise area of Sindhupalchowk District has been exposed to landslide hazard. Therefore, present study concentrates on landslide susceptibility mapping of the area along the road corridor of the Araniko Highway about 30 km from Bandeu to Barhabise, Sindhupalchowk District by using Arc GIS 10.3. Statistical index method was used to prepare the landslide susceptibility maps. The causative factors considered for the study were elevation, slope angle, slope aspect, geology, distance from drainage, distance from road, land use and rainfall. For the preparation of slope, aspect and elevation map a Cartosat image with 30 x 30 m resolution was used and for landuse, geology and distance from drainage and road factor data was taken from Department of Survey and for rainfall factor data of Department of Hydrology and Meteorology was used. The landslide susceptibility map shows that low, medium and high susceptibility zones covers 12.22%, 29.73% and 58% of the total area, respectively where 77.95% of the observed landslides fall under the high susceptibility zone. Thus, these maps can be used for slope management, land use planning and disaster management planning by the concerned authorities.

Hydrology and hydrogeological study in Musi Bayu Asin District, south of Sumatera

***Asti Sulastri, Jejen Ramdani, M Fauzan Septiana, and Andyono B. Santoso**

Mine Exploration, Technic and Desain Department, Bandung Institute of Technology and Science
**Corresponding author: astiacim@gmail.com*

The research area is located in Bayung Lencir District, Musi Banyu Asin Regency, South Sumatera Province is a coal mining area that plans to do mining. The study area has a tropical climate, in which there are streams entering the mining area. Hydrology and hydrogeology studies were conducted in order to estimate the potential of surface water to the pit and then performed preventive measures to reduce the accident rate use direct frequent analysis. The data used are the rainfall of the research area, the flow of the river flowing into the mining area plan and the topographic map. The total area of research is 4,999 ha, the catchment area is included in the mining plan of 2,748 ha, with each CA1 762 ha, CA2 431 ha, CA3 585 ha and CA4 970 ha. Maximum mean rainfall in the study area is 36.31 mm/day with rainfall intensity of 15.93 mm/h or 45.95 mm/day. The results of the research are estimated discharge for CA1 9.11 36.511 m^3/sec, CA2 6.06 m^3/sec, CA3 9.04 m^3/sec and CA4 14.68 m^3/sec, total discharge water debit entering pit of 36.511 m^3/hr. To overcome the potential of water entering the pit, it is necessary channel as recommended channel dimensions trapezoidal shape because it is more stable with wide channel 27.597 m^2.

Susceptibility zoning of complex landslides in Lanzhou City using logistic regression method

***Baoping Wen[1], Shu Jiang[1], Yongjun Zhang[2], and Ruidong Li[2]**

[1]*School of Water Resources and Environment, China University of Geosciences (Beijing), Beijing, China*
[2]*Gansu Institute of Geo-Environment Monitoring, Lanzhou, Gansu*
**Corresponding author: wenbp@cugb.edu.cn*

Due to its hilly terrain and vast distribution of thick loess soil as well as intensely adverse human activities, Lanzhou, the capital city of Gansu province, is one of cities which suffers from various types of landslide disasters, specifically and most severely slides, falls and debris flows in China. Since 1949, about 237 landslide incidents have occurred, leading to death of more than 650 people and economic losses of more than 650 million RMB (Ding and Li, 2009). It has been investigated that there are 179 unstable slopes and 93 potential debris flow gullies in the city. To provide a priority list of landslide prevention in terms of areas in the city for local decision makers, both susceptibility zoning of each type of landslide and overall landslides were evaluated using logistic regression method, which has been recognized to be one of the most popular technical tools for landslide susceptibility analysis (Regmi et al., 2014).

Since occurrence nature of each type of landslide is different, logistic regression model was developed for each type individually, including variables chosen for analysis, class of their categories, and size and shape of cell unit assigned for evaluation. Landslide-causing factors were chosen as variables for model development, and their categories or values were based on statistical analysis of the inventory data. Coverage ratio of vegetation, distance to faults and human activity were used for all types of the landslides. Slope angle, slope height and soil/rock type were used for slide and fall, while channel gradient ratio, drainage area and soil type were used for flow. Square shape of the cell unit with length of 20 m was employed for slide and fall, and drainage area of each gulley was used for debris flow. The logistic regression model was run coupling with a geographic information system (GIS).

The results of analysis show that the Lanzhou City is the most susceptible to slide among the three types of landslides, and the least susceptible to fall. In terms of area percentage, about 46%, 27% and 5% of the city are highly susceptible to slide, debris flow and fall, respectively with probability greater than 0.75, and about 43%, 27% and 86% of the city are not susceptible to slide, debris flow and fall, respectively with probability less than 0.1. For evaluating susceptibility of the overall landslide in the city, a weight coefficient was introduced based on percentage of disaster incidents of each landslide type. The results show that about 22% of the city is highly susceptible to landslides with probability greater than 0.75, and about 18% is not susceptible to landslides with probability less than 0.1 (Fig. 1). The results' accuracies for the three types of landslides and their overall, which were assessed based on inventory data, were 93%, 90%, 96% and 93%, respectively indicating that these results were quite reliable.

REFERENCES

Ding, Z.Q., and Li, Z. H, 2009, Geological Hazards and their Prevention in Lanzhou City. Gansu Publishing House of Science and Technology, Lanzhou. 472p. (In Chinese)

Regmi N.R, Giardino J.R. McDonald E.V., and Vitek J.D., 2014, A comparison of logistic regression-based models of susceptibility to landslides in western Colorado, USA, Landslides, v. 11, pp. 247–262.

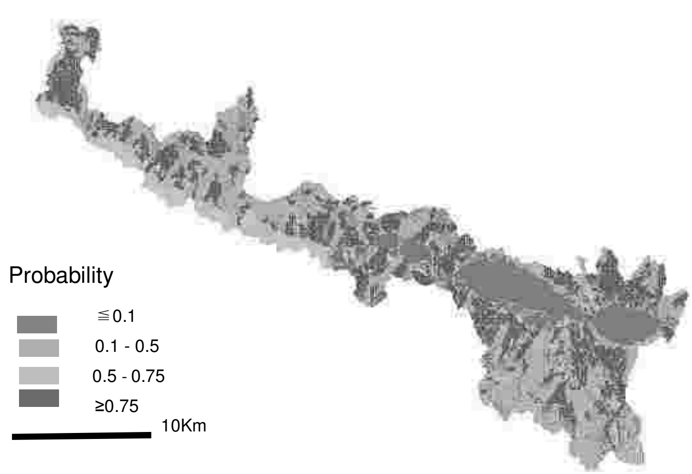


Fig. 1, Landslide probability map of Lanzhou city

Landslides induced by seismic events: an overview in France and Europe

Gilles Grandjean[1], Rosalie Vandromme [1], Séverine Bernardie[1], Olivier Sedan[2], and *Myriam Belvaux[1]

[1]*Risks and Prevention Division, BRGM, Orléans, France*
[2]*Water, Environment & Ecotechnologies Division, BRGM, Orléans, France*
**Corresponding author: m.belvaux@brgm.fr*

Landslide hazard assessment is the estimation of a target area where landslides of a particular type, volume, run out and intensity may occur within a given period. The first step to analyse landslide hazard consists of assessing the spatial and temporal failure probability (when the information is available, i.e. susceptibility assessment). Two types of approach are generally recommended to achieve this goal: qualitative (i.e. inventory-based methods and knowledge data driven methods) and quantitative (i.e. data-driven methods or deterministic physically-based methods).

To take into account heterogeneity of the materials, spatial variation of physical parameters, and landslides typology, BRGM, the French Geological Survey, has developed a physically-based model (PBM) implemented in a GIS environment (Fig. 1). This PBM couples a global hydrological model (GARDENIA®) including a transient unsaturated/saturated hydrological component with a physically-based model computing the stability of slopes (ALICE®, Assessment of Landslides Induced by Climatic Events) based on the Morgenstern-Price method for any slip surface. The variability of mechanical parameters is handled by the Monte Carlo method.

During the last years, the model has been applied at different scales for different geomorphological environments: (i) at regional scale (1:50,000-1:25,000) in the French West Indies and in the French Polynesian islands, (ii) at local scale (1:10,000) for two geologically complex mountainous areas, (iii) at the site-specific scale (1:2,000). In each study, the 3D geotechnical model has been adapted. The different studies have allowed: (i) to discuss the different factors included in the model especially the initial 3D geotechnical models; (ii) to precise the location of probable failure following different hydrological scenarii; and (iii) to test the effects of climatic change and land-use on slopes for two cases. For example, the model has been applied to understand the behaviour of a large landslide in the Reunion Island, where the extreme climatic conditions produce large deformations within the active landslide.

Finally, it is shown that it is possible to obtain reliable information about future slope failures at different scales for different scenarii with an integrated approach. The final information about landslide susceptibility (i.e. probability of failure) can be integrated in landslide hazard assessment and is an essential information source for future land-use planning.

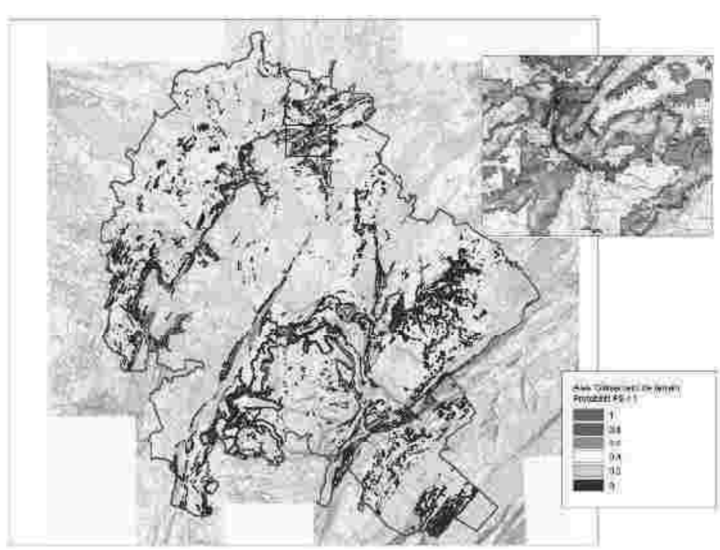


Fig. 1, Landslides hazard map for Jura department, France (from BRGM/RP-59065-FR)

Deterministic seismic hazard assessment made in 2013 for Budhi Gandaki dam, Nepal, and its comparison with the 2015 earthquakes

Julien Rey[1], Cécile Allanic[1], Marie L'Hostis[2], Laurent Bollinger[3], Thierry Winter[1], and *Myriam Belvaux[1]

[1]Risks and Prevention Division, BRGM, Orléans, France
[2]Tractebel Engineering S.A., Gennevilliers, France
[3]CEA/DAM/DASE/LDG, Bruyères-Le-Châtel, France
**Corresponding author: m.belvaux@brgm.fr*

The Government of Nepal is planning a major hydropower project on the Budhi Gandaki River delimiting the Gorkha and Dhading Districts, 55 km west of Kathmandu (Fig. 1). In 2013, a seismic hazard study was carried out to estimate the reference seismic motions to be taken into account for the design of the dam and its facilities. According to the deterministic approach, a seismotectonic analysis, a homogeneous catalog of seismicity and reference earthquakes were successively established.

Resulting from the collision between India and Asia, the Main Himalayan Thrustis segmented by transverse NE-SW faults. A 500 to 800 km long segment, the "central Himalayan seismic gap", between the epicentres of the great 1934 Nepal-Bihar (to the east) and the 1905 Kangra (to the west) earthquakes had not experienced a major quake for more than 500 years. At the time of our study, in 2013, the Budhi Gandaki dam project was located in this area of potentiallybig earthquakes. The last major earthquake in the "central Himalayan seismic gap" with a magnitude of 8.2 to 8.7 occurred in 1505 and strongly damaged the region. This 1505 historical event (M = 8.2 to 8.7) was the only one reference earthquake taken into accountand displaced to under the dam site at a depth of 8 km.

In accordance with ICOLD (1989) recommendations (version and 2010 update), an Operating Basis Earthquake (OBE) and a Maximum Design Earthquake (MDE) have been defined. The peak ground accelerations (PGA) were calculated between 0.77 g and 1.2 g for the MDE (M_w = 8.2–8.7) which is considered as the maximum possible earthquake (ICOLD, 2010). For Operating Basis Earthquake (OBE), we use the same reference earthquake but with magnitude reduced by 0.5 (M_w7.7) leading to a PGA of 0.61g. The horizontal elastic response spectra (5% damping) corresponding to the OBE and MDE are also given.

The major earthquakes of Spring 2015 in Gorkha occurred on tectonic structures located a few tenth of km from the dam. The aim of our presentation is to compare results from the 2013 seismic hazard study for design purposes, with observations resulting from the 2015 earthquakes.

REFERENCES

ICOLD, 1989. Selecting Seismic Parameters for large dams-Guidelines, Bulletin n°72.

ICOLD, 2010. Selecting Seismic Parameters for large dams-Guidelines, Revision Bull.n°72. Bulletin ICOLD Preprint n°148.

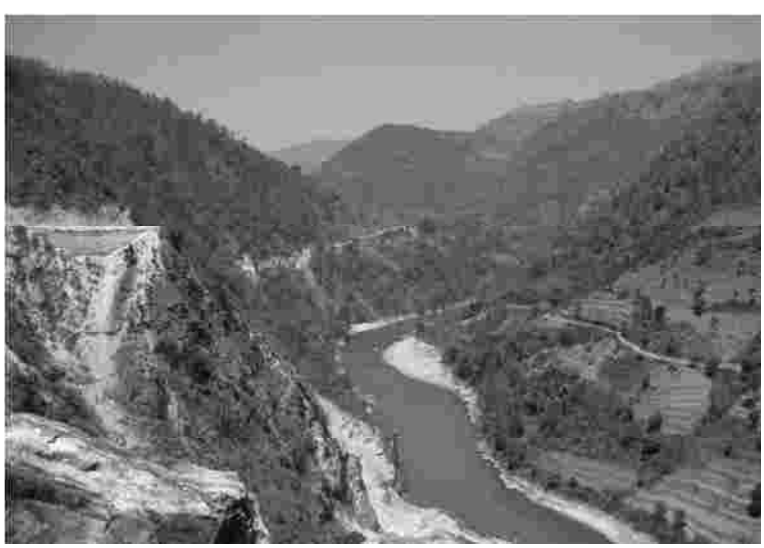


Fig. 1, Budhi Gandaki dam site around 2 km upstream of Benighat, Nepal (from www.bghep.gov.np)

Lithostratigraphical control on landslide in Babai Khola watershed of the Sub-Himalayan Zone, Nepal

***Bharat Prasad Bhandari[1], and Subodh Dhakal[2]**

[1]*Central Department of Environmental science, Tribhuvan University, Kirtipur, Nepal*
[2]*Department of Geology, Tri-Chandra Campus, Tribhuvan University, Kathmandu, Nepal*
**Corresponding author: bzenith11@gmail.com*

Sub-Himalayan zone also called Siwalik is located between the Main Boundary thrust (MBT) at north and Main Frontal thrust (MFT) at south. As a consequence of lithospheric plate, dynamics between the Indian Plate and Tibetan Plate, the young and fragile sedimentary rocks of the Chure area are highly weathered and deformed (TU-CDES, 2016). The Siwalik (Churia) Range is made up of geologically very young sedimentary rocks such as mudstones, shale, sandstones, siltstones and conglomerates (Dahal, 2012), due to such young and weak geological condition, trend of occurring different types of landslide is higher in the Siwalik zone. Present study was conducted in the Babai Khola watershed of Mid-Western Nepal. Geological map and landslide inventory map of study area was prepared. Landslide inventory map was prepared by using Google Earth pro, 2016 and it was verified by several Field study. Geological map was prepared in the field by detailed study of lithostratigraphy and geological structures.

Loosening of cementing materials in conglomerate is the major cause of debris fall, block slide and gully erosion in the Upper Siwalik. Red clay cementing materials of conglomerate undergoes weathering and makes the gravel loose and fragile. Highly weathered and easily erodible mudstone beds between thick sandstone beds are responsible for landslide in the Middle Siwalik. The mudstones in the Lower Siwalik are highly to completely weathered, which were in the form of residual soil in the surface at many places. These are less permeable but can be easily eroded by rain action due to soft nature and eroded mass are soluble with water and moved through erosional gullies. So that, several gully erosion, erosion induced landslide, mud flow, earth flow and mud slide were occurred in the Lower Siwalik.

REFERENCES

Dahal R.K., 2012, Rainfall-induced Landslide in Nepal, International Journal of Japan Erosion Control Engineering v. 5(1), pp 1–8.

TU-CDES, 2016, Landslide Inventory Characterization and Engineering Design for Mitigation Works of Chure Area in Ten Districts. Central Department of Environmental Science, Tribhuvan University and Government of Nepal, President Chure-Tarai Madhesh Conservation Development Board, Kathmandu.

Shear behavior of unfilled granitic joints with reference to weathering grade

***Bikash Kumar Ram, and Arindam Basu**

Department of Geology and Geophysics, Indian Institute of Technology Kharagpur, Kharagpur, India
**Corresponding author: bikashram@gg.iitkgp.ernet.in*

The shear strength of rock joints is considered as one of the most important parametersconcerning the stability of a rock mass. However, limited number of studies has focused on the influence of weathering on shear behavior of rock joints. This study explores the said issue consideringgranitic rocks from India.

The weathered granitic joint samples were collected from the natural exposure located at Dahanimara, Balasore town of Odisha, India. The weathering grades of the joint surfaces were assigned following the six-fold classification scheme (Anon, 1995) and subsequently, substantiated by rebound values obtained by applying the rebound hammer on the joint surfaces. Planarjoints with different weathering grades (Grade II and Grade III) were investigated. Multistage constant normal load direct shear tests were performed on each sample at three different increasing normal stresses within a range of 0.22–0.70 MPa (ISRM, 2015). Based on the test results in this study, the role of weathering in deteriorating peak shear strength and peak friction angle becomes evident (Fig. 1). The study also shows that such influence of weathering gets prominent with the increase in normal stresses (Fig. 1).

REFERENCES

Anon, 1995, The description and classification of weathered rocks for engineering purposes: Geological Society Engineering Group Working Party Report, Quaternary Journal of Engineering Geology, v. 28, pp. 207–242.

ISRM, 2015. The ISRM suggested methods for rock characterization, testing and monitoring: 2007–2014. In: Ulusay, R. (Ed.), Suggested Methods Prepared by the Commission on Testing Methods, International Society for Rock Mechanics. Springer, 293p.

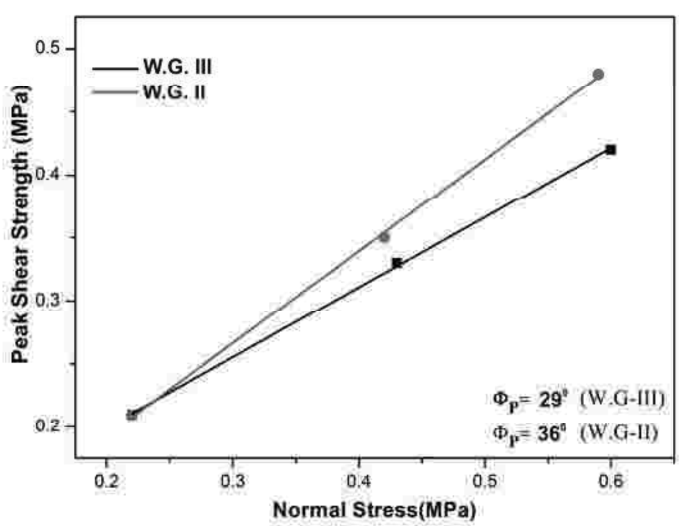


Fig.1, An example of peak shear strength vs normal stress plot with reference to weathering grade (ϕ_p: peak friction angle)

Mechanism and disasters characteristics of complex structural rock mass along the rapidly uplift section at the upstream of Jinsha River

***Chen Jianping, and Wang Qing**

College of Construction Engineering, Jilin University, Changchun, Jilin, China
**Corresponding author: chenjpwq@126.com*

Up reaches of the Jinsha River, located at the north part of the Hengduang Mountain, belong to the southeast margin of the Qinghai Tibet plateau. The research area is located at the deep valley with abundant water recourses and is subject to rapid uplift (Ming, 2012). The neotectonics is active since the middle and the late Pleistocene that gives rise to annual uplift value greater than 5 mm/a, and due to the Fohn effect the vertical climatic zonation is significant. The geological background is at high geostress. A complex structural rock mass, i.e. ophiolite suite, has developed in the Jinsha River plate tectonics joint belt. Huge potential disaster bodies such as ancient landslides, avalanches, debris flows and glacial deposits are almost continuously distributed along the up reaches of the Jinsha River.

According to the previous research material and features of uplift and subsidence in China (Qingsong et al., 1991), a concept of rapid uplift threshold equal or greater than 5 mm /a is recommended to the rapid uplift river section. Evidences and basic features related to four events of huge landslide dam residuals originated from different time and scale were enumerated. Fig. 1 shows one of the ancient landslide dam residuals.

The relationship between the rapidly uplifting river section and four landslide dams was expressed. Genetic mechanism of four huge landslide dams developed in the reach of 21.4 km river section was discussed and analysed based on geological process and mechanism. The earlier landslide dam residuals might be potentially hazardous for the future human activities, and is emphasized to be highly concerned issue.

REFERENCES

Ming, H., 2012, Present Crustal Vertical Movement of Eastern Tibetan Plateau and Coseismic and Post Seismic Vertical Deformation of Two Typical Earthquakes, Beijing. Institute of Geology, China Earthquake Administration.

Qingsong, Z., Yaofei, Z., and Xiangshun, L., 1991, The Problems of Present Uplifting Velocity of Tibet-Qinghai Plateau, Chinese Science Bulletin, v.7, pp. 529–531.

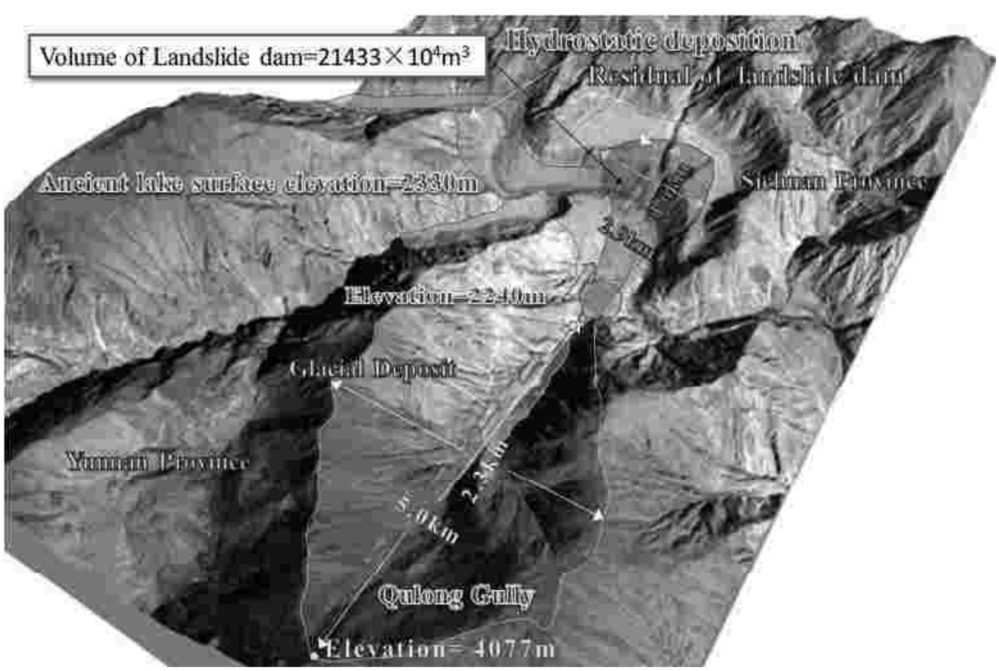


Fig. 1, Ancient landslide dam residual discovered at the up reaches of the Jinsha River

National-wide shallow landslide early warning system in Taiwan: modeling, assessment and validation

***Ching-Fang Lee[1], Cheng-Lung Chiu[2], and Li-Yuan Fei[2]**

[1]Disaster Prevention Technology Research Center, Sinotech Engineering Consultants, INC, Taipei, Taiwan, (R.O.C.)
[2]Central Geological Survey, Ministry of Economic Affairs, New Taipei City, Taiwan, (R.O.C.)
**Corresponding author: cflee@sinotech.org.tw*

Regional catastrophic landslides and debris slides triggered by typhoon events have occurred more frequently in recent years and caused considerable casualties and much economic loss in Taiwan. To reduce the damage and to prevent loss of life resulting from sediment-related hazards, this study collected 16-period landslide inventories which contained information pertaining to occurrence time, location, magnitude, rainfall intensity, accumulated rainfall to establish the rainfall threshold for shallow landslides on a regional scale. This study applied the concept of a hazard matrix which combined the magnitude (landslide ratio of slope units) and the susceptibility of occurrence (historical disaster records) to establish the rainfall thresholds for early warning. Accordingly, the critical rainfall thresholds were determined based on the R24 (24 hours accumulated rainfall) and I3 (3-hour mean rainfall intensity) of historical records.

Through the analysis of historical landslide data, both 3-hour mean rainfall intensity and 24-hour accumulated rainfall were incorporated into the analysis model developed in this project. As a result, errors associated with past models which failed to include precipitation records or only considered accumulated rainfall were corrected, and the accuracy of the model was improved. This improved assessment model resulted in the shallow landslide susceptibility model described in this study which had an overall accuracy of 70.9 % and an AUC value greater than 0.767. A validation result showed that the overall accuracy for the non-landslide slope units and was 73%. The landslide accuracy was 65%, and the AUC was 0.737. A validation result showed that the model could predict the possible sediment hazard on hillslope 2~9 hours prior to the occurrence of landslides. The web-GIS based early-warning system was also developed to display the real-time rainfall data (QPESUMS) and assess the warning signal immediately for disaster prevention through increasing the response time.

Currently, a Web-GIS system, which provides data for pre-disaster preparedness, disaster response and countermeasures, and post-disaster data management, has been established. Future rainfall data associated with landslides can be applied to improve the model which in turn will aid landslide predictions for debris flow torrents (source areas), assessments of landslide potential near mountainous highways, and the development of disaster prevention plans for remote villages.

REFERENCES

Lee, C.F., Huang, C.M., Tsao, T.C., Wei, L.W., Huang, W.K., Cheng, C.T., and Chi, C.C., 2016, Combining rainfall parameter and landslide susceptibility to forecast shallow landslide in Taiwan, Geotechnical Engineering Journal of the SEAGS & AGSSEA, v. 47, no. 2, pp.72–82.

Distribution map of landslides triggered by the 2015 Gorkha earthquake, Nepal

***Ching-Ying Tsou[1], Masahiro Chigira[2], Daisuke Higaki[1], Hiroshi Yagi[3], Vishnu Dangol[4], Shanmukhesh Amatya[5], Kazunori Hayashi[6], and Hiroki Kato[1]**

[1]Department of Agricultural and Environmental Engineering, Hirosaki University, Hirosaki, Aomori, Japan
[2]Disaster Prevention Research Institute, Kyoto University, Uji, Kyoto, Japan
[3]Department of Education, Art and Science, Yamagata University, Yamagata, Japan
[4]Department of Geology, Tribhuvan University, Kathmandu, Nepal
[5]Department of Water Induced Disaster Management, Ministry of Irrigation, Kathmandu, Nepal
[6]Okuyama Boring Co., Ltd., Sendai, Miyagi, Japan
**Corresponding author: tsou.chingying@hirosaki-u.ac.jp*

The 2015 Gorkha earthquake induced numerous mass movements in central Nepal. The main-shock occurred on 25 April, with a magnitude of M_w 7.8 and was followed by hundreds of aftershocks, including a M_w 7.3 on 12 May (USGS, 2015). In order to clarify the distribution of these landslides and their spatial relationship with topographic and geological factors, Google Earth satellite images were interpreted for both the pre- and post-mainshock and aftershock situation in an area of 7.8×10^3 km^2 of mountainous southern rim of the High Himalayan range. Field investigations were made for 2 weeks by using these images. Landslides were mapped as polygons and subdivided into two datasets consisting of new and enlarged landslides. New landslides are landslides that can only be recognized in the post-earthquake image, and enlarged landslides are landslides enlarged from pre-existing landslides in a pre-earthquake image and mapped together with the pre-existing landslides.

A total of 13097 new landslides and 750 enlarged landslides were identified and the most common types were shallow disrupted landslides. The areas of the individual landslides ranged from 10 to 3.2×10^5 m^2, covered a cumulative area of 5.4×10^7 m^2 or 0.7% of the study area. The landslide density was high in the Gorkha, Rasuwa, and Sindhupalchok districts, indicating these areas have suffered higher damage. Most commonly, landslides were on steep slopes of gneiss, quartzite, calcareous rocks, and slate. Besides, landslides were concentrated on steep slopes of more than 35° which are, related to the steep inner gorges, terrace edges, and geologically controlled in facing slopes. Steep slopes of the inner gorges and terrace edges are formed by the hillslope undercutting caused by rejuvenated river incision. Further quantitative analysis on weighting such geologic and topographic factors would be important for risk mapping to support planning and designing relocation and reconstruction programs.

The landslide mapping has been accomplished as a first version supported by the J-Rapid research Project of Japan Science and Technology Agency (JST) and is used in preparing landslide susceptibility map supported by JSPS KAKENHI Grant Number 16H03149-01.

REFERENCES

USGS, 2015, Magnitude in Nepal & aftershocks (Available at https://www2.usgs.gov/blogs/features/usgs_top_story/magnitude-7-8-earthquake-in-nepal/)

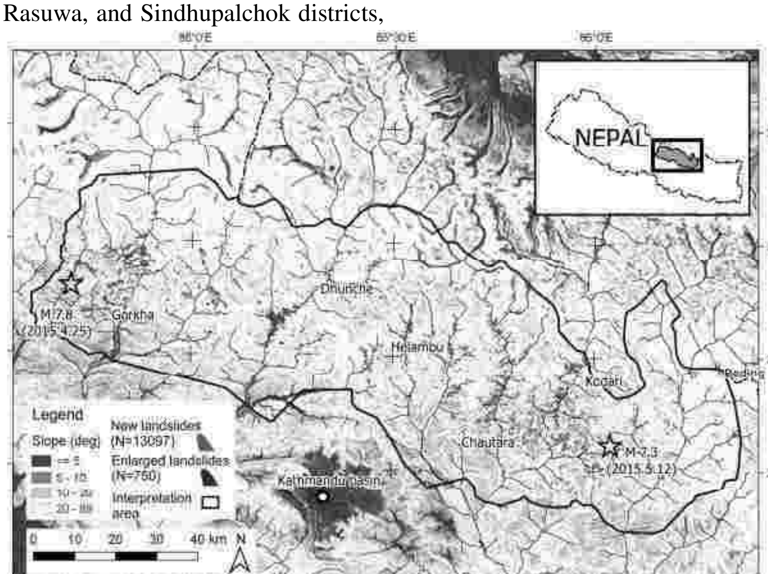


Fig. 1, Distribution map of landslides triggered by the 2015 Gorkha earthquake, Nepal

Numerical study of shear strength of non-persistent open joints with different normal stresses using PFC2D

Chonglang Wang[1,2], and *Shengwen Qi[1,2]

[1]*Key Laboratory of Shale Gas and Geoengineering, Institute of Geology and Geophysics, Chinese Academy of Sciences, Beijing, 100029, China*

[2]*College of Earth Sciences, University of Chinese Academy of Sciences, Beijing, 100049, China*

**Corresponding author: qishengwen@mail.iggcas.ac.cn*

The direct shear test is a practical approach to studying the mechanical properties of rock masses with discontinuities. Based on the test, the failure mechanism has been widely researched. However, the mechanical behavior of rock masses with intermittent joints is not clear yet. The direct shear test was simulated by Particle Flow Code 2D (PFC2D) to investigate the crack development patterns and shear strength at various normal loads. By numerical direct shear tests, the crack patterns under shear condition were visually observed, and the failure patterns were reasonable as well as the shear stress curves compared with experimental observation. The simulation results evidently showed the predominance of tension cracks in the crack development pattern under shear condition. These cracks started from the edge of the shear box symmetrically in the beginning, and later they also emerged at both tips of the joint due to the highly non-uniform stress distribution there. Moreover, it was observed that the peak shear strength envelope turns to be gentle under low normal stresses (0.3MPa-2MPa), which is different from that curve of intact rock masses.

Cross validation of event-based landslide susceptibility models at the Zengwen Reservoir catchment in southern Taiwan

*** Chyi-Tyi Lee, and Chih-Chieh Fu**

Graduate Institute of Applied Geology, National Central University, Taiwan
**Corresponding author: ct@ncu.edu.tw*

In the present study, we selected 9 independent rainstorms or typhoon events at the Zengwen Reservoir catchment to build 9 event-based landslide susceptibility models (Lee et al., 2008). These included the 1996 Typhoon Herb, 2001 Typhoon Toraji, 2004 Typhoon Mindulle, 20050615 rainstorm, 20060609 rainstorm, 2009 Typhoon Morakot, 20110718 rainstorm, 20120610 rainstorm, and 20150523 rainstorm events.

Each event-based landslide susceptibility model, which was built by logistic regression of topographic factors, geological factors, location factors, and triggering factors of landslide grids and non-landslide grids, was evaluated by using success rate curve method. Then, the 9 models were cross-validated between one event and another event by using prediction rate curve method. Results reveal that the prediction rates are fair to good and the performances of the 9 different models are stable.

Nine pre-event landslide inventories and 9 post-event landslide inventories were combined to form a multi-temporal landslide inventory of the study area. A logistic regression without triggering factors, same as the traditional method, was used to build a traditional landslide susceptibility model of the study region. At last, we compared the 9 basic susceptibility maps with this traditional susceptibility map, and found that they were similar in pattern, revealing that a common susceptibility pattern existed in the study region.

Basic susceptibility map is defined as a map constructed with neglecting triggering factors in the event-based landslide susceptibility model (Lee and Chung, 2017). We conclude that an event-based landslide susceptibility model is good in interpreting the landslides triggered by the event itself. It is also good in predicting landslides triggered by other events in the same region. The performances of the event-based landslide susceptibility models are stable. It is similar in map pattern with the traditional landslide susceptibility map trained by a multi-temporal landslide inventory, once triggering factors are removed from an event-based landslide susceptibility model.

REFERENCES

Lee, C. T., and Chung, C. C., 2017, Common patterns among different landslide susceptibility models of the same region, In: Advancing Culture of Living with Landslides, Mikos, M., Tiwari, B., Yin, Y.P., Sassa, K. (eds.), Springer International Publishing, v. 2, pp. 937–942.

Lee, C. T., Huang, C. C., Lee, J. F., Pan, K. L., Lin, M. L., and Dong, J. J., 2008, Statistical approach to earthquake-induced landslide susceptibility, Engineering Geology, v. 100 (1-2), pp. 43–58.

The use of remotely piloted aircraft systems for characterization and monitoring of landslides

***Daniele Giordan, Giorgio Lollino, Paolo Allasia, Marco Baldo, and Aleksandra Wrzesniak**

National Research Council, Research Institute for Hydrogeological Protection, Torino, Italy
**Corresponding author: daniele.giordan@irpi.cnr.it*

Remotely Piloted Aircraft Systems (RPAS) are nowadays considered a good alternative for the acquisition of orthophoto and digital surface models over small areas (Giordan et al., 2017). The low cost of these systems and the possibility to acquire, on demand, the same area many times, makes RPAS a valid solution for landslides characterization and monitoring applications. This innovative solution represents a possible alternative to the use of terrestrial and airborne LiDAR in particular for low vegetated areas. RPAS are usually equipped with optical sensors that acquire a sequence of images to be processed using structure from motion algorithms. The result obtained by applying this technique is a dense colored point cloud of the target from which it is possible to export DSM, mesh, and orthophoto. One of the most important advantages of RPAS is the possibility to fly very close to the target and to obtain a detailed representation of it (up to few cm/pixel). With respect to the terrestrial laser scanner (TLS), RPAS can acquire images from different points of view and reduce the presence of DSM's shadows. This possibility is important in particular for rockwalls, where the use of TLS is often limited by the availability of scan positions only near the bottom of the rockwall.

On the contrary, the use of photogrammetric solutions in strongly vegetated areas can hamper the possibility of making a good point cloud classification and it can reduce the possibility of obtaining a Digital Terrain Model (DTM). In this framework, airborne LiDAR seems to be the better solution as it can provide a detailed representation of ground geomorphological features.

This short introduction shows how it is hard to delineate guideline that defines when it is better to use one or the other system. The use of RPAS seems to be a good solution for limited gravitational phenomena also during emergencies to support decision makers in the definition of residual risk and in the first identification of occurred damages (Giordan et al., 2015a).

Another important application of RPAS is the acquisition of orthophoto for the landslide mapping. This application can be very useful in particular for gravitational processes that are characterized by a strong morphological evolution that requires a sequence of surveys.

Fiorucci et al. (2017), have analysed the use of RPAS for the creation of event landslide map. In their work, authors showed that the use of high resolution satellite images could be a good solution over large areas in particular if the target of the study was limited to the definition of landslides limit. On the contrary, if the target is the description of landslide geomorphological features and the identification of changes over the time, RPAS is the better choice.

In all cases, one of the most important element that influenced the choice of the RPAS typology (fixed wing or multirotors) is represented by morphological features of the studied area (Giordan et al., 2015b): multirotors are usually more indicated for steep slopes, rockfalls and rockslides studies and fixed wings are more suitable with gentle slopes and roto-translative slides.

REFERENCES

Fiorucci, F., Giordan, D., Santangelo, M., Dutto, F., Rossi, M., and Guzzetti F., 2017, Criteria for the optimal selection of remote sensing images to map event landslides, Nat. Hazards Earth Syst. Sci. Discuss, 23 p.

Giordan, D., Manconi, A., Remondino, F., and Nex, F., 2017, PREFACE Use of unmanned aerial vehicles in monitoring application and management of natural hazards. Geomatics, Natural Hazards and Risk, v. 8(1), pp. 1–4.

Giordan, D., Manconi, A., Facello, A., Baldo, M., Dell'Anese, F., Allasia, P., and Dutto, F., 2015a, Brief Communication: The use of an unmanned aerial vehicle in a rockfall emergency scenario. Nat. Hazards Earth Syst. Sci., v. 15, 163–169.

Giordan, D., Manconi, A., Tannant, D., Allasia, P., 2015b, UAV: low-cost remote sensing for high-resolution investigation of landslides. 2015 IEEE International Geoscience and Remote Sensing Symposium (IGARSS) Book Series: IEEE International Symposium on Geoscience and Remote Sensing IGARSS, pp. 5344–5347.

Journal of Nepal Geological Society, 2017, Vol. 54 (Sp. Issue)

Recognition of earthquake induced landslide in Khurkot Area, Central Nepal

Deepak Ghimire, Jyoti Khatiwoda, Suresh Adhikari, Nabin Sapkota, Aditya Dhungana, *Ranjan Kumar Dahal, and Suman Manandhar

Central Department of Geology, Tribhuvan University, Kirtipur, Kathmandu, Nepal
**Corresponding author: rkdahal@gmail.com*

Landslides are one of the immediate effects of earthquake. Numerous landslides may occur in great earthquakes ranging upto many kilometers. These processes cause significant changes in the landscape and damming rivers which produce effects that persist due to mega earthquakes.

The characteristics of old earthquake induced landslide mass movements are studied in Nigalepani Danda in Ramechhap District of Central Nepal. Geologically, the area lies on Kuncha Formation of Lesser Himalayan Zone with intercalation of gritty phyllite and quartzite.

The old landslide mass on Nigalepani area of Khurkot governs no distinct drainage pattern together with sparse vegetation on the hummocky terrain. Least vegetation with no traces of bedrock in the toe region and Scarp near the ridge and flow direction from the pebble imbrication suggest the formation of such topography by huge landslide possibly triggered by earthquake. Orientation of joints along the toe and near the scarp have been analyzed to understand the movement in geological planes after earthquake of past. Results of joints shows the scarp is directed towards North to North-East while the toe shows random direction, some of them are joint controlled and some are slope controlled.

The orientation and displacement of joint peak value in displaced mass in comparison with scarp and, less drainage density in the area suggested that the whole area was moved in the ancient time due to mega earthquake. Although the date of earthquake is not known, it was confirmed that the many large earthquakes hit the Lesser Himalayan region and their damage signatures are still recorded in the slopes of the Midlands.

Integrated monitoring system for landslides impacting linear infrastructures: the case of the Pietrafitta earth flow, Southern Italy

***Paola Revellino[1], Luigi Guerriero[1], Gerardo Grelle[2], Neri Mascellaro[1], and Francesco M. Guadagno[1]**

[1] *Department of Science and Technology, University of Sannio, Benevento, Italy*
[2]*Department of Civil Building and Environmental Engineering, Sapienza University, Rome, Italy*
**Corresponding author: paola.revellino@unisannio.it*

The Pietrafitta earth flow is an active landslide which involves the national road SS87 connecting the cities of Benevento and Campobasso in Southern Italy. Mobilizing flysch and clay sequences, the earth flow has a length of 250 m from the source area to the toe and a width of about 100 m on the accumulation area. Due to the landslide, since 2014, only one lane of the SS87 allows the passage of the motor vehicles in an alternating way, whereas the other lane is occupied by part of the landslide toe.

In order to mitigate the risk of sudden invasions of landslide material on the transit lane and to design mitigation measures, an integrated monitoring system of the earth flow displacement was installed in March 2016 consisting of: 1) a Ground-based synthetic aperture radar interferometry (GBInSAR), located in front of the landslide on the opposite slope and with an accuracy of less than 1 mm and an acquisition rate of 4 minutes; 2) an automatic Total Station (Robotic station), located near the GBInSAR, looking at 23 reflectors with acquisition rate of 20 minutes; 3) multi-temporal scans with terrestrial laser scanner (TLS); 4) a video surveillance system, installed at the toe and h24 working; and 5) an experimental low-cost Arduino®-based wire extensometer (Guerriero et al., 2017) placed along the left flank of the earth flow toe.

The joint use of different accurate monitoring techniques allowed to detect not only real-time displacement of the landslide body but also critical conditions of movement acceleration or material invasion on the road. The integration and comparison among different displacement information from the simultaneous combination of different monitoring techniques adequately allowed to undertake safety countermeasure and alert procedures to stop the traffic at the right time on the road.

REFERENCES

Guerriero, L., Guerriero, G., Grelle, G., Guadagno, F. M., and Revellino, P., 2017, Brief Communication: A low-cost Arduino®-based wire extensometer for earth flow monitoring, Nat. Hazards Earth Syst. Sci., v. 17, pp. 881–885, https://doi.org/10.5194/nhess-17-881-2017.

An impact-induced fragmentation model for predicting the runout of brittle fragmentable rockfall

***Gang Luo[1,2], Jin Tao[1], Hu Xiewen[1], Fu Jiankang[1], and Mei Xuefeng[1]**

[1]*Department of Geological Engineering, Faculty of Geosciences and Environmental Engineering, Southwest Jiaotong University, Chengdu 610031, China*
[2]*Department of Civil and Structural Engineering, Faculty of Engineering, University of Sheffield, Sheffield, S1 3JD, United Kingdom*
**Corresponding author: luogang@home.swjtu.edu.cn*

Large volume rockfalls initiated from hundreds of meters escarpment can produce plenty of comminuted fragments with high velocities after the explosive collision at the impacting zone. Particularly, the fragments would pose significant threats to infrastructures, lives and properties due to their extremely high velocities and disastrous long runouts. To reveal the nature of the mechanism and to elaborate the micromechanical process during the instantaneous collision, two-dimensional impact-induced fragmentation model of a brittle fragmentable rockfall crushing on a rigid plane is proposed. Furthermore, some experimental results were used to verify the derived mathematical equations of this model. The results indicate that the calculation results coincide well with the actual metrical data. It is thought that the proposed collision fragmentation model can provide a great insight into the kinetics of rockfalls and predict the most dangerous runout of these rock fragments, which is crucial for lifeline engineering.

Analysis of two different landslides concern on mitigation design and cost estimation based on ground condition and mechanism of Chure Region, Kailali District

Gaurab Singh Thapa*[1], Subodh Dhakal[2], and Suman Panday[1]

[1]*Central Department of Environmental science, Tribhuvan University, Kirtipur, Kathmandu, Nepal*
[2]*Department of Geology, Tri-chandra Campus,Tribhuvan University,Ghantaghar Kathmandu*
**Corresponding author: gst199281@gmail.com*

Landslides that are highly vulnerable and that have posed high risk to the people, infrastructures and environment are given priority for the mitigation design. So far as possible, the practicability for implementation and cost effective designs are recommended. The costing for the recommended mitigation measures are based on latest respective district rates.

Based on the cause and effect of landslide, and detail characterization of landslides, four major groups of mitigation measures are recommended namely modification of slope geometry, drainage management, retaining structures and internal slope reinforcement. While recommending the mitigation measures, five factors namely engineering feasibility, economic feasibility, legal/regulatory conformity, social acceptability, and environmental acceptability are also considered. Geotechnical references of the landslide sites are also obtained from laboratory analysis of samples collected from the field and the in situ test using portable machines such as Shear Vane and Pocket Penetrometer. Different test performed in the laboratory are Direct Shear Test, Grain size distribution, Liquid limit and Plastic limit test, Water Content test and Specific Gravity test.

In Chure, two different types of Landslides were observed, one of them require application of external force like retaining walls, drainage, check dam, soil nailing, rock bolts, river training structures and Bio-engineering technique to increase the resisting force for slope stabilization. The cost of mitigation measures to be implemented in one of the landslides of Kailali District with similar case was found to be NRs 10236675.82. This cost include the cost of check dam of cross section 3.5 mx2.5 m, surface drainage, subsurface drainage, gabion retaining wall of height 3.5 m and base width 2 m and 5 spurs of height 3 m, length 20 m and spacing 50 m. Laboratory data used for the design, to this particular case are cohesion 21.58 KN/m^2, angle of internal friction 32º, grain size distribution curve, specific gravity 2.71 and water absorption 0.47%.

Whereas in most of the landslides bioengineering techniques alone will be adequate, construction of bioengineering systems like live check dam, palisades, fascines, grass seeding, tree and shrub planting were used for stabilizing slopes. This concept is used in small site where the erosion and shallow plane failure are the only likely failures. It is the low cost techniques for protecting slopes and stabilizing shallow failure.

The cost of bioengineering techniques to be implemented in next landslides with similar case was found to be NRs 869579.69. This cost includes the cost of live check dam, grass seeding and front stepped gabion toe wall of 2 m height and 1.5 m base width. The cost of both cases was calculated based on 074-075 District rate. The cost excludes 15% overhead and 13% VAT.

In overall, from the analysis we can conclude that mitigation design and cost mostly depends on landslide activity, morphology, geology, soil condition and hydrology.

Calibration and performance of numerical models to simulate the recent Xinmo landslide (Sichuan, China) and assess secondary hazard

***Gianvito Scaringi, Xuanmei Fan, Qiang Xu, Guillem Domènech, Fan Yang, and Lanxin Dai**

State Key Laboratory of Geohazard Prevention and Geoenvironment Protection, Chengdu University of Technology, 610059, Chengdu, Sichuan, China
**Corresponding author: g.scaringi@qq.com*

On June 24th, 2017, a catastrophic rock avalanche destroyed Xinmo, a village in Maoxian, Sichuan, China, causing a large number of fatalities (Fan et al., 2017). Further potentially unstable masses have been identified in the landslide source area and, among them, a 4.5 million m^3 mass raised serious concerns. Field monitoring and a reliable secondary risk assessment are fundamental to protect the infrastructure and the population still living in the valley. Thus, soon after the landslide occurrence, we used very-high resolution mapping and laboratory testing to perform numerical simulations – using discrete element methods (DEM) and continuum methods (CM) to reproduce the landslide and simulate the kinematics and runout of the potentially unstable mass, which could cause a new catastrophic event (Scaringi et al., 2017).

Both DEM and CM models provided satisfactory results in terms of kinematics and topography of the deposit (Fig. 1). The simulations also highlighted that, in case of failure of the potentially unstable mass, the new landslide deposit could possibly block the river course again and could reach also several still-inhabited buildings and a portion of road infrastructure. Furthermore, the possible river damming and breaching could trigger a new hazard chain.

The process of modelling and the engineering practice include assumptions and simplifications. Their aim is, in fact, to provide reasonable approximations which are practically useful, for instance, to make predictions. Within this framework, none of the models employed in this work can be thought to absolutely prevail over the others. Nevertheless, a discriminant can be thought based on the practical usability of the model and its results, in terms of the ease of use, number and physical meaning of the input parameters, the possibility of incorporating the model into early warning systems and the computational time. The simultaneous use of multiple modelling approaches, to limit model-specific shortcomings and take the model-related variability into account explicitly, would be surely beneficial.

The simulation of possible future landslides using back-analysis and laboratory testing for parameters calibration, and field monitoring for the identification of potential instabilities are important tools for local-scale risk assessments. When a timely response is critical, the model computational performance becomes fundamental: the ability of promptly re-computing a new solution from spatially-distributed inputs from continuous field monitoring is fundamental for dynamic risk assessments and early warning systems at a scale of detail, and can save lives.

REFERENCES

Fan, X., Xu, Q., Scaringi, G., Dai, L., Li, W., Dong, X., Zhu, X., Pei, X., 2017, Failure mechanism and kinematics of the deadly June 24th 2017 Xinmo landslide, Maoxian, Sichuan, China. Landslides (tentatively accepted).

Scaringi, G., Fan, X., Xu, Q., Liu, C., Ouyang, C., Domènech, G., Yang, F., Dai, L., 2017, Some considerations on numerical methods to simulate past landslides and possible new failures: the case of the recent Xinmo landslide (Sichuan, China). Landslides (under review).

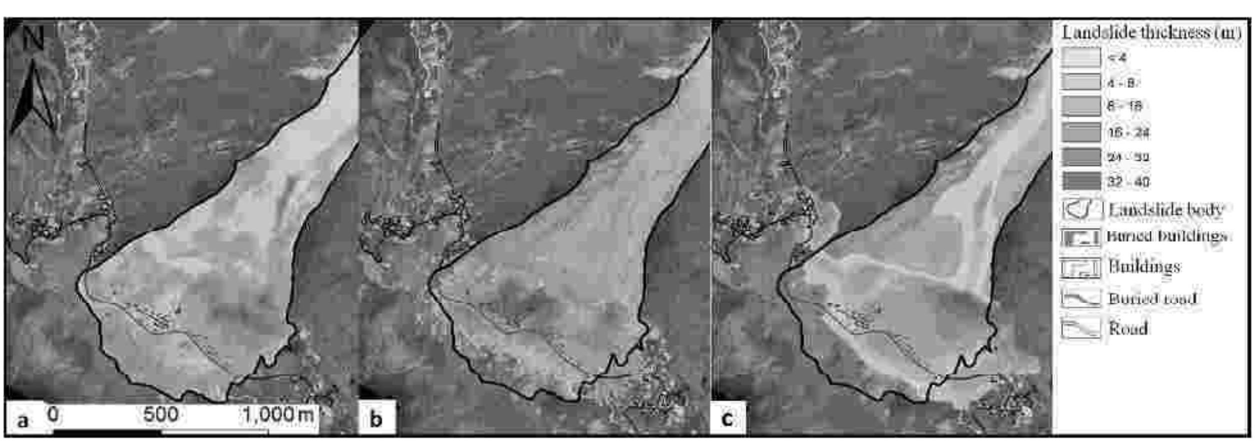


Fig. 1, Area and thickness of the 24th June 2017 Xinmo landslide: (a) actual deposit, obtained by comparing the pre-sliding and post-sliding digital elevation models, (b) results of the simulations carried out with PFC and (c) the simulations carried out with MassMov2D

Towards a chemo-mechanical approach to landslide stabilization

***Gianvito Scaringi[1], Caterina Di Maio[2], Xuanmei Fan[1], Dario M. Pontolillo[2], Jacopo De Rosa[2], and Qiang Xu[1]**

[1]State Key Laboratory of Geohazard Prevention and Geoenvironment Protection, Chengdu University of Technology, 610059, Chengdu, Sichuan, China
[2]School of Engineering, University of Basilicata, 85100, Potenza, Basilicata, Italy
**Corresponding author:* g.scaringi@qq.com

Clay-rich soils are widespread throughout the globe. Their mechanical properties can be deeply affected by the chemical composition of the pore fluid. As an example, Fig. 1a shows the residual friction angle evaluated on specimens of an illitic soil of marine origin, in equilibrium with the natural pore fluid, with distilled water or with two different salt solutions at different concentrations. In loessic soils too, which can contain up to 30% of clay (mainly illite), the magnitude of the chemo-mechanical effects has been shown to be noticeable (Fig. 1b). Several Authors (Scaringi, 2016) hypothesized connections between changes in pore fluid chemistry and activity of some types of landslides in clay soils. In a slow earthflow in a marine clay formation, Di Maio et al. (2015) showed that the pore ion concentration can decrease significantly from the depth towards the ground surface (Fig. 1c). Thus, different parts of the landslide shear zone may exhibit different values of shear strength parameters. Natural and anthropic processes (e.g. exposure to rain water, irrigation water, freshwater from confining aquifers) can cause the concentration to decrease further over time, leading to further weakening which can produce shear displacements (Di Maio and Scaringi, 2016). On the other hand, an increase of pore solution concentration, e.g. through ion diffusion from salt piles (Di Maio et al., 2016; 2017) can produce strength increase (as in Fig. 1a). The role of chemo-mechanical coupling in the initiation and movement of landslides in clay soils should be evaluated explicitly, as it can be fundamental for a correct assessment and management of the landslide risk. Furthermore, applications of the chemo-mechanical concepts can lead to innovative and environment-friendly solutions of landslide stabilization, based, for instance, on engineered modifications of the clay behavior driven through the pore fluid chemistry.

REFERENCES

Di Maio, C., and Scaringi, G., 2016. Shear displacements of a clay in the residual condition induced by decrease in pore solution concentration. Engineering Geology, v. 200, pp. 1–9, doi: 10.1016/j.enggeo.2015.11.007.

Di Maio, C., Scaringi, G., Vassallo, R., 2015. Residual strength and creep behaviour on the slip surface of specimens of a landslide in marine origin clay shales: influence of pore fluid composition. Landslides, V. 12 (4), pp. 657–667, doi: 10.1007/s10346-014-0511-z.

Di Maio, C., Scaringi, G., Vassallo, G., Perrone, A., Rizzo, E., 2016. Variations in pore fluid composition within a landslide in clay shales of marine origin and their influence on its mechanical behaviour. In: Landslides and Engineered Slopes. Experience, Theory and Practice, pp. 813–820, doi: 10.1201/b21520-95.

Di Maio, C., Vassallo, R., Scaringi, G., De Rosa, J., Pontolillo, D. M., 2017. Monitoring and analysis of an earthflow in tectonized clay shales and study of a remedial intervention by KCl wells. Italian Geotechnical Journal (in press), doi: 10.19199/2017.2.0557-1405.031.

Fan, X., Xu, Q., Scaringi, G., Li, S., Peng, D., 2017. A chemo-mechanical insight into the failure mechanism of frequently-occurred landslides in the Loess Plateau, Gansu Province, China. Engineering Geology, v. 228, pp. 337–345, doi: 10.1016/j.enggeo.2017.09.003.

Scaringi, G., 2016. Influence of pore fluid composition on clay behaviour and chemo-mechanical study of a clayey landslide. PhD Thesis, doi: 10.13140/RG.2.2.32935.24486.

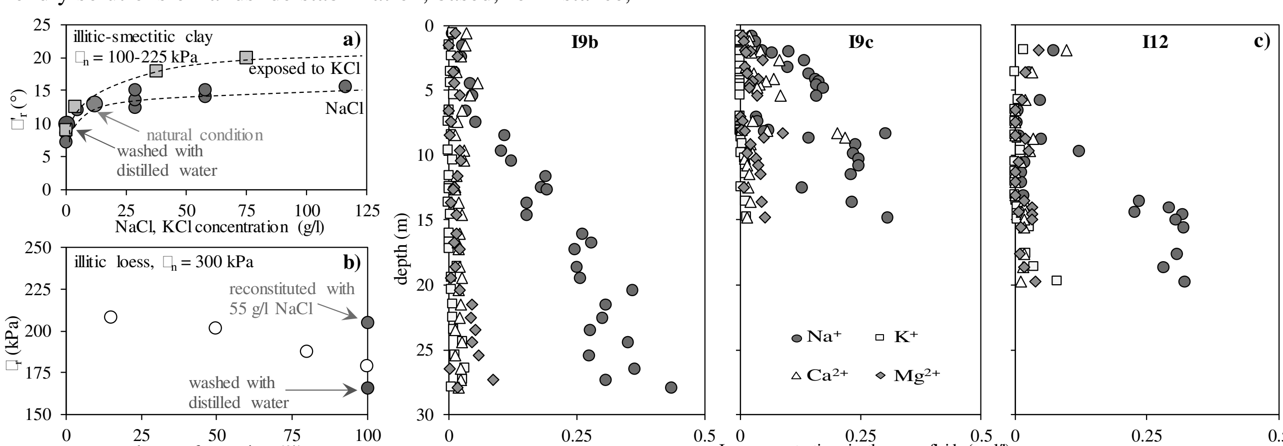


Fig. 1, (a) Effect of salt concentration on the residual friction angle of an illitic-smectitic clay (Di Maio et al., 2017); (b) effect of pore saturation and fluid chemistry on the shear strength of an illitic loess (Fan et al., 2017); (c) ion concentration in the pore fluid evaluated in a slow earthflow in a marine clay formation (Di Maio et al., 2015)

Rock fall run out analysis: Batu Caves, Selangor, Malaysia

***Goh Thian Lai[1], Ailie Sofyiana Serasa[2], Abdul Ghani Md Rafek[3], Norbert Simon[1], and Tuan Rusli Mohammed[4]**

[1]School of Environment and Natural Resource Sciences, Faculty of Science and Technology, Universiti Kebangsaan Malaysia,43600 UKM Bangi, Selangor, Malaysia
[2]Chemical & Petroleum Engineering Department, Faculty of Engineering, Technology and Built Environment (FETBE), UCSI University, 56000 Cheras, Kuala Lumpur, Malaysia
[3]Department of Geosciences, Universiti Teknologi PETRONAS,Bandar Seri Iskandar, 31750, Tronoh, Perak Darul Ridzuan
[4]Minerals and Geoscience Department Malaysia, Jalan Sultan Azlan Shah, 31400 Ipoh, Perak, Malaysia
**Corresponding author: gdsbgoh@gmail.com*

Rockfall events are quite common in Malaysia. Episodes of rockfall events pose a significant threat to areas where development is being built in close proximity to mountaineous topography. Due to the needs of rapid urban development in Malaysia, buildings are now being built near limestone cliffs which may be exposed to the risk of rockfalls. An effective planning and co-ordination is a good starting point in exploring the probability of rockfall events particularly those of high magnitude. Therefore, the aim of this study was to identify the geohazard zonning using rockfall simulation. With regard to the arising rockfall problem, this paper presents the kinematics of a rockfall zoning study of a limestone hill (Abbruzzese and Labiouse, 2014; Norbert et al., 2015) at Gua Damai, Batu Caves, Selangor, Malaysia. The instability phenomenon poses a significant threat as there is an extreme activity park and urban neighborhoods located at the base of the limestone hill. In order to investigate the existing condition of the slopes and decide upon the rockfall protection and mitigation, rockfall analyses were conducted for three main slope sections S1, S2 and S3 which were extrapolated to the entire rock slopes in describing the intensity and hazard levels. From the rockfall run out trajectory results, distance of high hazard zone, intermediate hazard zone and low hazard zone ranges from 7–11 m, 51–89 m and 59–100 m, respectively. A hazard map was produced based on the rockfall trajectory simulation results, which depicted areas that are having different degree of risks against any potential rockfall occurrences. This assessment is expected to be useful as a case study of rockfall analysis and assessment in Malaysia to quantify the potential impact of rockfall occurences on human safety and infrastructures.

REFERENCES

Abbruzzese, J. M. and Labiouse, V. 2014. New Cadanav methodology for quantitative rock fall hazard assessment and zoning at the local scale. Journal of the Consortium on Landslides, pp. 551–564.

Norbert, S., Muhammad Fahmi, A.G., Goh, T.L, Abdul Ghani, R., Azimah, H., Rodeano, R. and Lee, K.E. 2015. Assessment of rockfall potential of limestone hills in the Kinta Valley. Journal of Sustainability Science and Management, v. 10 (2), pp. 24–34.

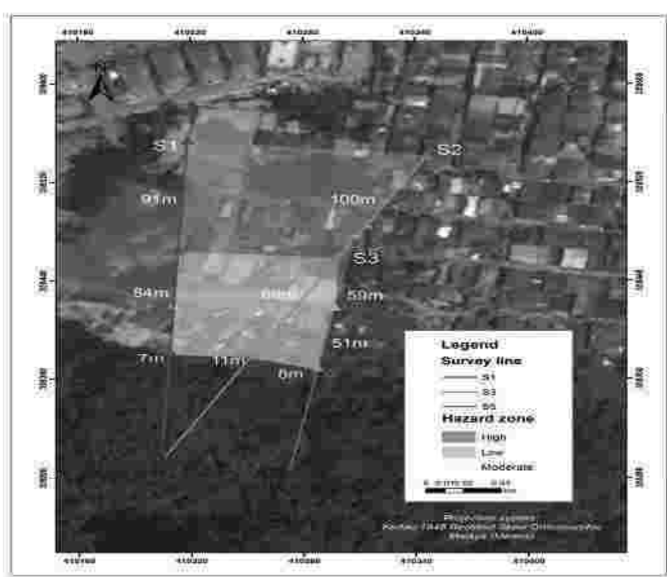


Fig. 1, Hazard map produced based on the results of the distanct range of hazard zones taken from the toe of cliff for slope S1, S2 and S3

The characteristics of landslides in metamorphic rock area of the Duhe River Basin in China

***Guangli Xu[1], Zhigang Li[1], Xin Zhao[2], and Yongpeng Fu[2]**

[1]*Institute of Geological Survey, China University of Geosciences, Wuhan Hubei, China*
[2]*Geological Survey Center in Wuhan, China Geological Survey, Wuhan Hubei, China*
**Corresponding author: lzgdyy@hotmail.com*

The Duhe River Basin on northwest of Hubei province is one of China's frequent geological disasters occurring districts, which are characterized by lithologically complicated soft, loose and broken metamorphic rocks. This research is based on the data of 770 landslides investigated by the China Geological Survey in about 2500 km^2 metamorphic rock area of the Duhe River Basin, The present study statistically analysed the distribution, classification, geometrical characteristics and failure modes of landslides, and introduced two rock landslides with typical failure modes. The results showed that the distribution of the landslides in the metamorphic rock area is dominated by topography, formation lithology, geological structure, river and human engineering activities. The significant characteristics of the landslides in the metamorphic rock area are large quantity, small scale, and small altitude difference between front and rear edge, small thickness of landslide body and large numbers of landslides along the bedding planes. The rock landslides are affected by the bedding planes, and their main failure modes are the sliding along or cutting the bedding planes.

Landslides triggered by the 2008 Wenchuan Earthquake: temporal evolution of the frequency-size distribution

***Guillem Domènech, Xuanmei Fan, Lanxin Dai , and Qin Yang**

State Key Laboratory of Geohazard Prevention and Geoenvironment Protection, Chengdu University of Technology, 610059, Chengdu, Sichuan, China
**Corresponding author: guillem.domenech@qq.com*

After a big earthquake, an intense mass wasting over large areas is produced delivering up to several billions of cubic metres of loose material that can lead to devastating mass movements (co-seismic landslides). Many of these loose deposits are stored in the hillslopes as source material for landslide and debris flow reactivations (post-seismic reactivations). During intense rainfalls, mostly in the wet seasons, the hillslope material is transferred into the main channels as debris flows and its long-term impact may affect the population for several years. Nevertheless, this effect has been seen to decrease over the time due to the decreasing of channel sediments, self-slope stabilization and vegetation recovery.

During the Wenchuan earthquake on 12 May 2008 in the Sichuan Province (China), more than 60,000 landslides were triggered over an area of 35,000 km^2 (Huang and Fan, 2013). With the aim of analysing the evolution of the co-seismic and post-seismic landslides in terms of number of reactivations and size, the frequency-size distributions of the co-seismic and post-seismic landslides for the periods 2008, 2011, 2013 and 2015 have been calculated. Such distributions are usually built up from landslide inventories and they are typically approximated to a power law relation. In many cases, a roll-over effect is produced which is usually related with undersampling of low-size landslides (Stark and Hovius, 2001). However, some authors suggest that the roll over is given in too many large occurrences to be considered as data biasing, and some physical reason must be responsible for.

In this study, a new extensive and detailed multi-temporal inventory mapping of the co-seismic and post-earthquake reactivations and new landslides has been carried out for 2008, 2011, 2013 and 2015. The site is located around Yingxiu and Longchi towns, and it extends over an area of 500 km^2, characterized by rugged mountains with altitudes that range from 420 m to 4000 m asl and steep slope gradients up to 69 º.

Results presented in Fig. 1 show that, as expected, the highest number of landslides was given in 2008, during the earthquake, when the co-seismic landslides were triggered. Afterwards, between the period 2008 and 2011, the frequency of the post-seismic landslides remained very similar. Nevertheless, during the following years 2013 and 2015, the number of instabilities was reduced considerably. With regard to the area of the instabilities, the shifting of the roll-over point through larger areas, observed mostly during the mapping carried out in 2013 and 2015, indicates a decreasing of the number of small-sized landslides.

These preliminary results provide valuable insights about the evolution of the landslides triggered during the 12 May 2008 Wenchuan earthquake. However, further studies for a better understanding of the changes on the material delivered in areas affected by earthquakes are required.

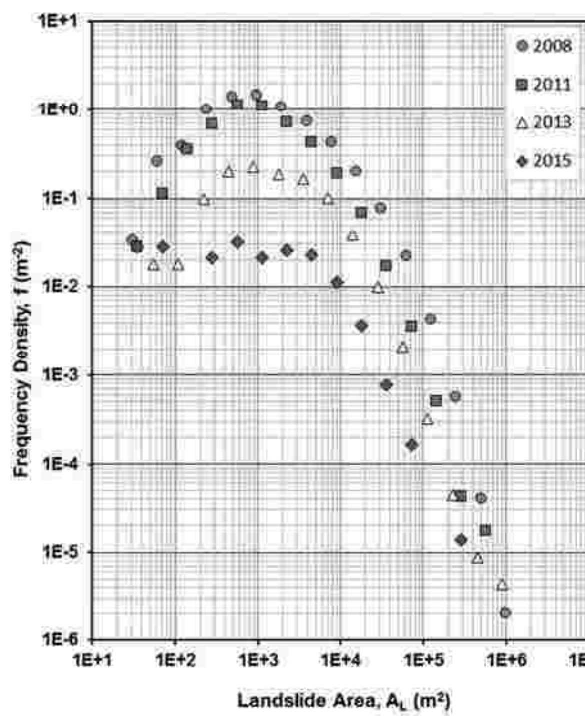


Fig. 1, Frequency size distribution of the co-seismic landslides (2008) and the post-seismic reactivations (2011, 2013 and 2015)

REFERENCES

Huang, R. and Fan, X., 2013. The landslide story. Nat Geosci, v. 6, pp. 325–326. doi: 10.1038/ngeo1806

Stark, C.P. and Hovius, N., 2001. The characterization of landslide size distributions. Geophys Res Lett, v. 28, pp. 1091–1094.

Landslide multi-hazard risk assessment, preparedness and early warning in South Asia: integrating meteorology, landscape and society (LANDSLIP)

*** Helen Reeves [1], Bruce Malamud [2], and LANDSLIP Consortium[3]**

[1]*British Geological Survey, Environmental Science Centre, Keyworth, Nottingham, NG12 5GG, UK*
[2]*Department of Geography, King's College London, Strand, London WC2R 2LS, UK*
[3]*www.landslip.org/consortium.html*
**Corresponding author: hjre@bgs.ac.uk*

About 13% of Indian land mass is prone to landslides, with the Himalaya and Western Ghats regions particularly prone due to climate, geomorphology and geology. Rainfall and earthquakes are the main triggers of these landslides, coupled with poor land management practices and increased development. The impact of landslides on people, business, culture and heritage can be considerable and wide-ranging, including fatalities, loss of agricultural land and infrastructure, and damage to ecosystems. LANDSLIP is a four-year research grant that will address an aim to reduce impacts of hydrologically related landslide multi-hazards (in terms of fatalities, livelihoods, assets) and build resilience to landslides in vulnerable (often remote) and hazard prone areas of South Asia. LANDSLIP brings together 36 physical and social scientists from three academic (KCL, Newcastle, Amrita), four government (BGS, CNR-IRPI, GSI, Met Office) and two non-governmental organisations (Practical Action UK/India) in India, the UK and Italy.

LANDSLIP's overall objectives are the following:

(i) To enhance risk assessment and monitoring for hydrologically controlled landslides and related hazards in two main Indian study regions (Nilgiris & Darjeeling/East Sikkim), with a focus on identifying landslide-relevant weather patterns (Neal et al. 2016), landslide domains and rainfall thresholds (Guzzetti et al., 2008), societal factors and the interaction of 'cascading' hazards (Gill and Malamud, 2016).

(ii) To develop methodologies on a regional to catchment spatial scale and a seasonal to daily temporal scale (Fig. 1).

(iii) To strengthen understanding of the underlying drivers of risk toward more integrated, multi-hazard landslide risk monitoring and warning systems.

(iv) To get the right landslide information to the right people in the right ways (e.g., early warning systems, mobile networks, web-based gathering and dissemination of information to national/regional/local stakeholders including the public) including research to enhance the uptake and use of risk information in practice. LANDSLIP will explore replicability of methodologies developed in LANDSLIP for other landslide prone regions such as Uttarakhand, India and disseminate LANDSLIP project knowledge to the wider region of Southeast Asia (in particular, Afghanistan).

Through advances in interdisciplinary science and application in practice, the collective ambition of this consortium is to contribute to better landslide risk assessment and early warning in a multi-hazard framework, and, by working with communities, better preparedness for hydrologically controlled landslides and related hazards.

REFERENCES

Gill, J.C. and Malamud, B.D., 2016. Hazard interactions and interaction networks (cascades) within multi-hazard methodologies. Earth System Dynamics, v. 7, pp. 659–679.

Guzzetti, F., Peruccacci, S., Rossi, M., and Stark, C.P., 2008. The rainfall intensity–duration control of shallow landslides and debris flows: an update. Landslides, v. 5, pp. 3–17.

Neal, R., Fereday, D., Crocker, R. and Comer, R.E., 2016. A flexible approach to defining weather patterns & their application in weather forecasting over Europe. Meteorological Applications, v. 23, no. 3, pp. 389–400.

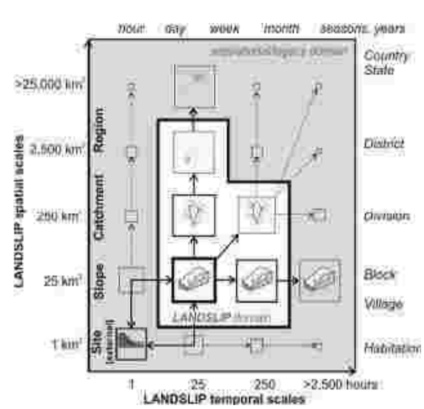


Fig. 1, Spatial & temporal scales addressed in LANDSLIP project (white box)

Study of co-seismic rockfalls in Greece

***Haris Saroglou[1], and Dimitrios Zekkos[2]**

[1]*Department of Geotechnics, School of Civil Engineering, National Technical University Athens, Athens, Greece*
[2]*Department of Civil and Environmental Engineering, University of Michigan, Ann Arbor, United States*
**Corresponding author: saroglou@central.ntua.gr*

Earthquakes can trigger rockfalls at great distances from the epicentre. Many examples of such cases exist in literature, e.g. in the 2010 earthquake in Chile, where many rockfalls were triggered at a distance of 400 km (Wick et. al, 2010), the 2005 earthquake in Kashmir (Basharat and Rohn, 2015), the 2010-2011 Canterbury earthquakes in New Zealand (Macey et al., 2016), the 2015 Nepal earthquake and others. Harp and Jibson (2002) proposed that concentrated seismically triggered rockfalls might result from local amplification of seismic shaking.

The effect of earthquakes on the occurrence of rockfalls is twofold: 1) the magnitude and epicenter distance of an earthquake define whether an unstable block will be detached from a rock slope. The possibility of a rockfall outbreak is also controlled by local topographic conditions (amplification of ground motion) and other site effects and 2) the peak ground velocity exerted by an earthquake determines the displacement magnitude of a rock block. Depending on the existing aperture of discontinuities, defining individual blocks, the resulting displacement from an earthquake can cause detachment of an unstable block. Keefer (1984) developed a magnitude – source distance chart for landslides, which can also be applied for rockfalls (Fig. 1). The dashed curve presents the maximum distances from fault rupture zones at which disrupted slides and falls have been observed worldwide.

The scope of this paper is to re-visit the major cases of co-seismic rockfalls in Greece, in order to identify the earthquake characteristics and investigate their effect on the triggering of rockfall events. Additionally, new techniques, such as UAV, and their use for the reconnaissance and modeling of co-seismic rockfalls, are demonstrated through selected examples from two recent earthquakes in Lefkada and Cephallonia Islands in Western Greece (Saroglou et al., 2017). Numerous rockfalls were triggered by historical earthquakes in Greece, as reported by Ambraseys and Jackson (1990) and Saroglou (2016). In the present study, a number of major co-seismic rockfall events in Greece have been studied and the magnitude – source distance chart of these rockfall events has been determined, using the chart proposed by Keefer (1984), as presented in Figure 1. The earthquakes have occurred in the period between 1981 and 2015. The magnitude of earthquakes that triggered rockfalls is between Mw= 5.7 and 6.7, while the maximum distance from the epicenter to a reported rockfall was 37 km. The peak ground acceleration of the nearest record to the rockfall site ranged between 0.24 5o 0.64. The main impact of these co-seismic rockfalls was damage to infrastructure (roadways and houses), while a number of rockfall incidents impacted Cultural Heritage sites.

REFERENCES

Ambraseys N.N. and Jackson J.A., 1990, Seismicity and associated strain of central Greece between 1890 and 1988. Geophys. J. Int., v. 101, pp. 663–708.

Basharat, M. and Rohn, J., 2015, Effects of volume on travel distance of mass movements triggered by the 2005 Kashmir earthquake, in the Northeast Himalayas of Pakistan. Nat Hazards, v. 77, pp. 273–292.

Harp EL. and Jibson, R.W., 2002, Anomalous concentrations of seismically triggered rockfalls in Pacoima Canyon: Are they caused by highly susceptible slopes or local amplification of seismic shaking? Bulletin of the Seismological Society of America, v. 92(8), pp. 3180–3189

Keefer, D. K., 1984, Landslides caused by earthquakes. Geol. Soc. Am. Bull., v. 95, pp. 406–421.

Massey C., Della Pasqua I F., Holden I C., Kaiser I A., Richards I L., Wartman I J., McSaveney I M. J., Archibald I, G., Yetton I M., Janku I L. (2016). Rock slope response to strong earthquake shaking. Landslides, DOI 10.1007/s10346-016-0684-8.

Saroglou H., 2016, Rockfall Susceptibility in Greece and Study of Coseismic Events. Proc. of 15th Symposium on Engineering Geology and Geotechnics, Belgrade.

Saroglou H., Zekkos D., Asteriou P., Marin C., Manousakis J., Tsiambaos G., 2017, Field Evidence and trajectory modeling of an earthquake triggered rockfall in Lefkada. Nat. Hazards Earth Syst. Sci. Discuss., doi:10.5194/nhess-2017-29.

Wick, E., Baumann, V., and Jaboyedoff, M., 2010, "Report on the impact of the 27 February 2010 earthquake (Chile, Mw 8.8) on rockfalls in the Las Cuevas valley, Argentina" Nat. Hazards Earth Syst. Sci., v. 10, pp. 1989–1993.

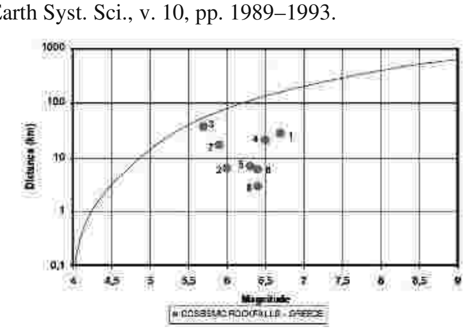


Fig. 1, Magnitude – distance chart for Greek co-seismic rockfalls. Earthquakes: 1. Corinthos (1981), 2. Kalamata (1986), 3. Konitsa (1996), 4. Skyros Island (2001), 5 and 8. Lefkada Island (2003, 2015), 6. Achaia (2008), 7. Cephallonia Island (2014)

A study on the contribution of roughness component to peak friction angle of rock discontinuities

***Hemant Kumar Singh, and Arindam Basu**

Department of Geology and Geophysics, Indian Institute of Technology Kharagpur, Kharagpur, India
**Corresponding author: hemant@gg.iitkgp.ernet.in*

Peak friction angle of discontinuities is an important parameter which often controls the stability of a rock masse at shallow depth. Surface roughness influences the peak friction angle of rock discontinuities and researchers studied this issue considering either discontinuity-replica or induced rock discontinuities. However, the contribution of roughness component to peak friction angle concerning the strength of discontinuity surface materials does not seem to have gained much attention. This study explores the said issue considering three rock types, i.e., granite, quartzite, and sandstone, from India.

In this study, a total of 15 rock samples (5 from each of granite, quartzite and sandstone) with natural discontinuities and their replicas were encapsulated for the laboratory direct shear test. The investigation involved the shearing at three consecutively increasing normal stresses within a range of 0.22–0.71 MPa for all samples. The peak friction angle (assumed to be the sum of basic friction angle and asperity angle (i.e. roughness component) was determined using the traditional technique for each natural rock discontinuity and its replica. The basic friction angle was estimated for the concerned rocks and their replicas by performing direct shear test on saw-cut samples and this was substantiated by the tilt test as well. The peak friction angle is plotted against the sample number (Fig. 1). Figure 1 depicts that in case of granite and quartzite samples, the contribution of roughness component towards peak friction angle is more than that of the corresponding replicas which can be attributed to much higher strength of these rocks than their corresponding replicas. On the other hand, in case of sandstone samples, the contribution of roughness component towards peak friction angle is, in general, almost similar to that of their replicas. This is because of the ferruginous coating on the sandstone bedding plane which causes very low frictional resistance to shearing.

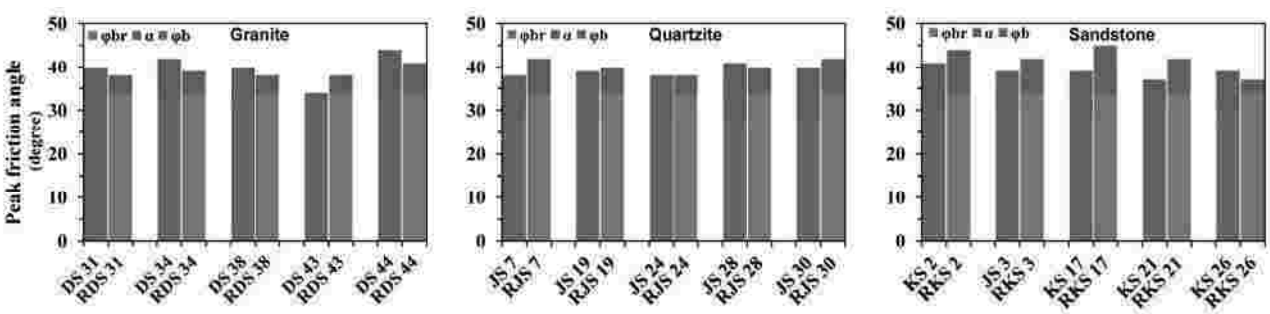


Fig. 1, Peak friction angle plotted against sample number (*Note:* φb: basic friction angle of rock discontinuity; φbr: basic friction angle of discontinuity-replica; and α: roughness component)

Geomorphological and geochemical approaches to clarify sediment distribution in mountain stream area, northern Kyushu, Japan

***Hiro Ikemi[1], Ryunosuke Nakanishi[1], Hendra Pachri[2], Yasuhiro Mitani[1], and Yuki Okajima[1]**

[1]Department of Civil Engineering, Kyushu University, Fukuoka, Japan
[2]Department of Geology, Hasanuddin University, Makassar-South Sulawesi, Indonesia.
**Corresponding author: ikemi@kyudai.jp*

From the viewpoint of comprehensive sediment management related to environment and disaster prevention over a catchment, it is important to quantitatively evaluate the sediment movement in mountain streams. Moreover, the frequency of sediment disasters in urban area originated from debris flows in mountain streams are increasing in Japan. Recent examples include the Hiroshima heavy rain disaster in 2014 and the northern Kyushu heavy rain disaster in 2017. The sediment movement in mountain streams such as debris flows is one of natural phenomena that supplies sediment to rivers. However, due to land-use change and human-induced landform since 1950, the boundaries between mountainous stream area and urban area have increased without any barriers such as farm land (Ikemi, 2017). As a result, debris flows in mountain stream area have often been causing sediment disasters. Then, the distribution and dynamics of sediments in mountain stream area should be related to the sediment disasters in urban area now in Japan.

We initiate to clarify sediment distribution and its movement in the temperate stream area, using geomorphological and geochemical methods. In this paper, we report the results of examining the sediment distribution in the mountainous catchment based on beryllium-10 contents of river sediment, topographic analysis by a process-based model, and dissolved-silica contents in river water.

Three watershed areas: A, B, and C have been surveyed in this study, which are located in the upper stream of the Umi River in the northern part of Kyushu. In this area, heavy rain disasters in 2003 caused over 700 mountain slope failures. As a result of the previous investigation, most of the collapse were shallow landslides and their distribution was prominent especially in the watershed C. The geology is mostly composed of Mesozoic granitic rocks widely distributed in northern Kyushu. These granitic rocks are generally known to have often caused shallow landslides due to deep-weathering. Moreover, we have confirmed higher specific flow rates in the granitic rocks regions than other geological regions by the preliminary surveys

In the process-based model, topography is formed by crustal deformation, hillslope processes, and fluvial processes. Its model formula is expressed by contributing area, topographic curvature and gradient. The study area was analyzed using this model with 5m-DEM obtained by the airborne laser survey. The results show that the topography is steeper, more convex, and that the influence by running water is relatively small in the catchment B. The measurement of flow rates during the dry season reveal that the specific flow rates were lower on the west side, and that the lowest specific flow rate was observed especially in the watershed B. Comparing the watershed B and C, the specific flow rate was always low and the dissolved silica concentration was always high in the watershed B. The measurement of the beryllium-10 content for the riverbed sediment samples has indicated a relatively large erosion rate of the watershed C. The topographic curvature is used as an indicator related to the thickness of soil layers. If we can interpret that the relatively smooth watersheds, such as the watershed C, have thick soil layers in hillslope due to high erosion rates, the cause of high specific flow rates in the watershed C could be due to groundwater accumulated in thicker soil layers. Low dissolved-silica contents observed in the watershed C is consistent with the above assumption.

This study, by the process-based topographic analysis using detailed DEM, shows the possibility to obtain semi-quantitative characteristics regarding to hydrology and sediment dynamics in mountainous catchments. We believe that the proposed method can also be used for evaluation and prediction of sediment disaster hazards.

REFERENCES

Ikemi, H., 2017, Geologically constrained changes to landforms caused by human activities in the 20th century: A case study from Fukuoka Prefecture, Japan, Applied Geography, v. 87, pp. 115–126.

Drainage density as rainfall induced landslides susceptibility index in a small catchment area

***Hirohisa Kinoshita[1], Shuich Hasegawa[2], Atsuko Nonomura[2], and Shingi Nakai[1]**

[1]*Fukken Co., Ltd. ,Hiroshima, Japan*
[2]*Department of Safety System Construction Engineering, Kagawa University, Takamatsu, Japan*
**Corresponding author: h-kinoshita@fukken.co.jp*

Drainage density has been defined as total stream length per unit area of a river basin (Horton, 1945). Numerous researchers have measured values of drainage density from topographic maps and have analysed variables controlling drainage density and found that drainage density is related to climate, vegetation, bedrock geology, and time. Usually, it is noticed that increasing drainage density is always responsible to the slope failure. Onda (1993) noticed that terrain having higher drainage density and thin soil layer was comparatively damaged more by shallow seated landslide. Hasegawa et al. (2009) noticed that during heavy rainfall, area having higher drainage density is usually prone to shallow-seated landslide whereas large scale landslide is frequent in area having lesser drainage density (Fig. 1). In this context, this paper describes some of aspects of drainage density and its relation to the rainfall index for landslides and debris flows in southwest Japan. In this study, total 34 debris flows and landslides whose occurrence times are confirmed were selected for the study from Hiroshima disasters in 1999, Bofu disasters in 2009, Shobara disasters in 2010 and Kii Mountains disasters in 2011 (Fig. 2). The catchment areas, which have source areas of sever debris flow disasters, were selected for drainage density calculation and the latter was compared with rainfall indices at the occurrence of flows and landslides.

REFERENCES

Hasegawa S., Yamanaka M., Mimura T., Dahal R.K., and Nonomura A., 2009, Drainage density as rainfall-induced landslides susceptibility index; International Seminar on Hazard Management for Sustainable Development in Kathmandu, Nepal, pp. 72–75.

Horton, R. E., 1945, Erosional development of streams and their drainage basins: hydrophysical approach to quantitative morphology, Geological Society of America Bulletin, 50, 275–370.

Onda, Y., 1993, Underlying rock type controls of hydrological processes and shallow landslide occurrence IAHS Publ. no. 217, pp.47–55.

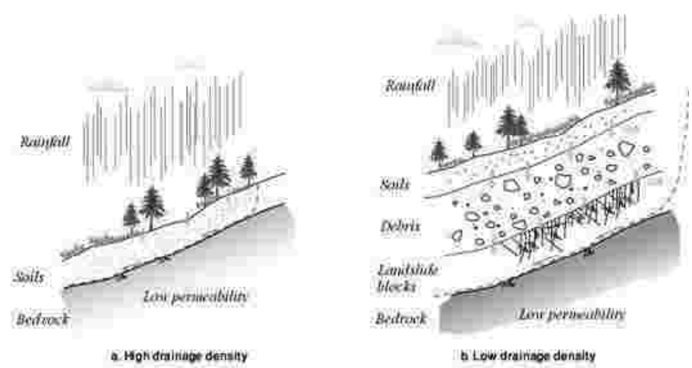


Fig. 1, Relation between drainage density and hydrological structure of slopes (Hasegawa et al., 2009)

Fig. 2, The study area in southwest Japan

Topographic condition of landslide occurrence location caused by the 2015 Gorkha earthquake, Nepal

***Hiroki Kato, Ching-in Tsou, Daisuke Higaki**

Graduate School of Agriculture and Life Science, Hirosaki University, Hirosaki, Japan
Faculty of Agriculture and Life Science, Hirosaki University, Hirosaki, Japan
**Corresponding author:kunkh82@gmail.com*

On April 25, 2015, the Gorkha earthquake with the moment magnitude 7.8 occurred in central Nepal. In order to reduce the landslide disaster risks by earthquakes, we aim to clarify topographical causes of landslides induced by the Gorkha earthquake through the distribution analysis on landslides. The study area is set in the upper Trishuli River basin in central Nepal. Based on the interpretation of the Google earth images before and after the earthquake, the number of extracted earthquake landslide is 867, and many of them have elongated features (Fig. 1). The reason for this is that shallow landslides with long travel distance were dominated mainly on rocky slopes with large relief. We analyzed the topographic condition of the landslide source area employing ArcGIS10.0 in which the AW3D 5 m DEM is used. As a result, landslides occurred on the slopes with the gradient of 30° to 70°, which is steeper than the average gradient of 20° to 45° in the study area. The orientation of landslide source area dominates in the south and southeast directions, which is almost same as the prominent slope direction in this area. In addition, 69% of the landslides is located in the inner gorge which has been formed by active up-lifting and incising erosion. Slope gradient and the existence of inner gorge are considered to be important topographic conditions of earthquake landslides.

REFERENCES

Ambraseys, N. N., and Melville, C. P., 2002, Historical Seismicity and Tectonics: The Case of the Eastern Mediterranean and the Middle East. International handbook of earthquake and engineering seismology, v. 81A, pp. 1-951.

Maggi, A., D. McKenzie, and K. Priestley, 2000, Earthquake focal depths, effective elastic thickness, and the strength of the continental lithosphere, Geology, v. 28, pp. 495–498.

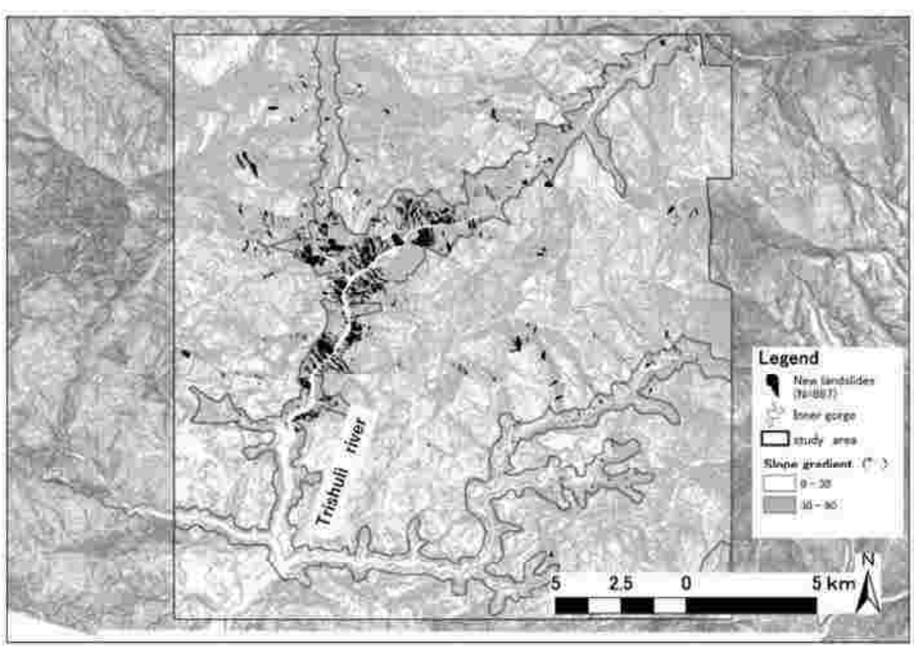


Fig.1, Distribution of earthquake landslides, slope gradient and inner gorges

Dormant landslides distributed in upper course of Sun Kosi watershed and landslides induced by Nepal Gorkha Earthquake 2015

***Hiroshi Yagi[1], Kazunari Hayashi[2], Daisuke Higaki[3], Ching-Ying Tsuo[3] and Go Sato[4]**

[1]Faculty of Education, Yamagata University, Kojirakawa, Yamagata, Japan
[2]Okuyama Boring Co.Ltd., Yokokote, Japan
[3]Faculty of Agriculture and Life Science, Hirosaki University, Bunkyocho, Hirosaki, Japan
[4]Faculty of Modern Life, Teikyo-Heisei University, Nakano, Tokyo, Japan
**Corresponding author: yagi@e.yamagata-u.ac.jp*

Dormant landslides of deep-seated type distributed in the upper course of the Sun Kosi watershed; the Sun Kosi-Bhote Kosi area and the Indrawati area, were detected by 3D interpretation of aerial photographs. Dormant landslides of the deep-seated type are predominantly distributed in geological areas of gneiss, phyllite, considering the number of the site and planar dimension. Scale of dormant landslide also becomes larger in the area of gneiss. They show trend of sliding orientation towards northwest, reflecting the geological structure. Its biggest one is wider than 10 square kilometers. Gravitational deformation has also proceeded in the gneiss area, forming multiple ridges widely.

Innumerous landslides were induced by Nepal Gorkha Earthquake 2015 in mountain slopes just above the hypocenter plane. The authors made an inventory mapping of the earthquake induced landslides, detected by Google Earth images taken after the earthquake. Most of them are shallow landslides, occurred just below break of slope along the deep gorge of which angle is 26–50 degrees. They are concentrated in the geological area of slate, dolomite, schist and gneiss. Fig. 1 is a superimposed map of earthquake induced landslide inventory onto the dormant landslide inventory. However, reactivation of the dormant landslide of the deep-seated type is not observed. The authors attribute that to rare precipitation before the earthquake. It occurred in the end of dry season, therefore ground water level was presumably low to activate the dormant landslides.

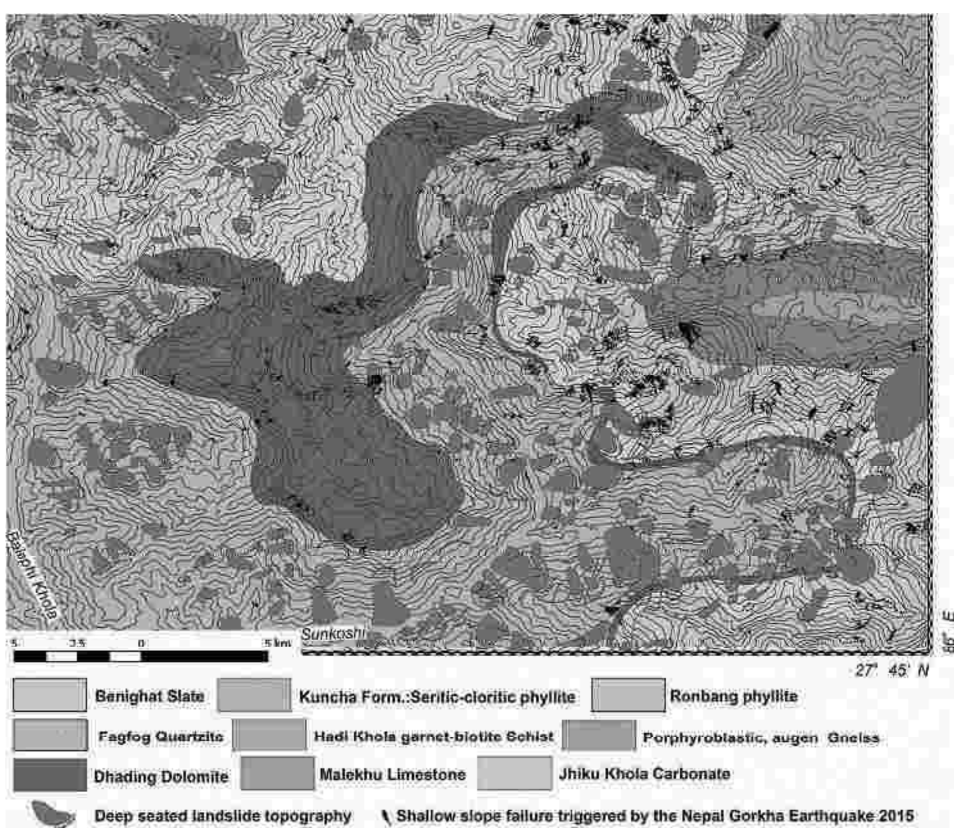


Fig. 1, Landslides inventory of dormant landslides and earthquake induced landslides

Runout distribution analysis of debris flow in the Southern Mountainous region of Bandung, West Java, Indonesia

***Imam A. Sadisun, Rendy D. Kartiko, and Indra A. Dinata**

[1]*Department of Geological Engineering, Institut Teknologi Bandung, Bandung, Indonesia*
**Corresponding author: imam@gc.itb.ac.id*

The occurrence of several landslides followed by the debris flow, such as Cililin Landslide on April 21, 2004, Jember Landslide on January 2, 2006, Ciwidey Landslide on February 23, 2010 (Triana et al., 2013) and Mukapayung Landslide has make a lot of casualties and very terrible destruction in the southern mountainous region of Bandung, West Java. In general, debris flow zonation can be divided into three parts, which are source area, flow track and depositional area of debris materials. This study will focus on run-out modeling of debris materials, since the flow of debris materials started to distribution of debris materials in the depositional area, which is usually found in the plain areas of foot slope. Some of debris flow events are selected to be modeled in this research by mean of numerical simulation technique with Graphical User Interface (GUI) through software known as Kanako Version 2.00 Debris Flow Numerical Simulator (Nakatani et al., 2008).

Debris flow event in Tenjolaya Village, Bandung, West Java, February 23, 2010 with scenario viscosity value of 0.45 shows the flow rate of debris materials in depositional area is about 6 km/hour. Meanwhile in the flow track, the flow rate of debris materials reaching ±20 km/hour. The volume of debris materials that flow from the slope is estimated about 40 thousand m^3. The time needed for debris materials to reach the depositional area is estimated for 900 seconds (15 minutes). Debris flow event in Mukapayung Village, West Bandung, West Java, March 25, 2013 have been modeled using scenario viscosity 0.4 and the existing of boulders. This scenario shows that the flow rate of debris flow in the flow track reaching ±20 km/hour, while in the depositional area reaching ±6 km/hour. These boulders of andesite are located ±250 meters from the source area. The volume of debris materials that flow to the southeast toward the depositional area estimated about 30 thousand m3. The time required by the debris materials to flow from the source area to depositional estimated about 400 seconds (around 6 minutes).

REFERENCES

Nakatani, K., Wada, T., Mizuyama, T. and Satofuka, Y., 2008. Development of "Kanako" a wide use 1-D & 2-D debris flow simulator equipped with GUI, Proc. 2nd Intl. Conf. on Debris Flow, The Wessex Institute, UK.

Triana, Y. D., Sadisun, I. A. and Sumaryono, 2013. Debris flow from Dewata tea plantation landslide, Pasirjambu District, Bandung Regency, *Proceedings HAGI-IAGI Joint Convention Medan 2013*, October, pp. 28-31.

Landslide assessment along Ramche-Jharlang area in Dhading, Rasuwa and Nuwakot districts, Lesser Himalaya, Central Nepal

***Jharendra K.C., Purushottam Neupane, Deepak Gautam, and Kabi Raj Paudyal**

Central Department of Geology, Tribhuvan University, Kirtipur, Kathmandu, Nepal
**Corresponding author: jharendrakc03@gmail.com*

Landslide is the major hazard for Nepal. Most of the landslides are concentrated along the river valley, road cut sections, cultivated lands and geologically adverse areas like fault zones, incompetent lithology, steep slopes and overhang cliffs. Present study represents a small part of the Mahabharat Range within the Lesser Himalaya. Landslide inventory mapping was carried out along the Ramche-Jharlang area as this area consists of numerous landslide, small to large, affecting to ecology and society. The main objective of the investigation was to delineate landslides of different scales with detailed characterization and distribution of past landslides focusing on the present propagating trends in terms of its cause. The soul interest of this investigation is to note and provide information about the status of landslides in this range of Nepal Himalaya to the national and international community with a view of taking long-term solution. The field investigation was carried out by field work in the landslide occurring areas, visual inspection, satellite image analysis, photographical analysis, interaction and interview with the locals and the affected groups. The area is mapped as a highly prone area for landslide. The categorization and classification of landslides was done based on the standard classification (Varnes, 1978) and rules. Present study revealed to delineate type of landslide, landslide geometry, geology, hydrogeology, slope geometry, triggering causes of landslide and its impacts. It reveals nail scratching outlook in most of the hills. The slope failures can be classified as debris flow, rock slide, debris slide, rock fall, mud flow and deep seated creeps. There are several reasons for occurring such small to large scale landslides. The utmost reason is inherently weak geological setting along with some adverse geological structures in addition to the triggering factors like concentrated precipitation and earthquakes. From Ramche landslide in the eastern part to the Jharlang-Chhyamthali in the western part, have been threatening the people now and then. All these devastating landslides witnessed a huge loss of lives and destruction of properties. Systematic landslide hazard mapping and mitigation measures based on the cause and consequences at and during the planning and construction activities of infrastructures are fundamental steps to reduce loss from landslide disaster in the region.

Engineering geomorphological characteristics of the glacial lake outburst flood induced catastrophic creeping landslide: Ikhu Landslide in Central Nepal

***Kaushal Raj Gnyawali[1], Basanta Raj Adhikari[2], Kristen Cook[3], and Bibek Giri[4]**

[1]*State Key Laboratory of Ocean Engineering, Shanghai Jiao Tong University, Shanghai 200240, China*
[2]*Center for Disaster Studies, Institute of Engineering, Tribhuvan University, Pulchowk, Nepal*
[3]*GFZ Potsdam, GFZ Section 5.1, Potsdam, Germany*
[4]*Central Department of Geology, Tribhuvan University, Nepal*
**Corresponding author: kaushal.raj.gnyawali@gmail.com*

Rivers originating from glacial lakes in the Upper Himalaya and rushing in through high gradient hills pose a serious threat of cascading natural hazards downstream. The glacial lake outburst flood 5 July 2016 caused cascading floods and landslides in the Bhotekoshi River valley of Central Nepal. The region had been an area of high seismic activity during the April-May Gorkha earthquake and subsequent aftershocks loosening the slope materials. River incision caused the removal of lateral support at the foot of the slopes resulting in the downward movement of the slope and the displacement of the road (Araniko Highway) and adjacent settlements tremendously modifying the landscape and causing major disasters. The Ikhu Landslide complex nearby Tatopani, in Nepal-China border is a typical case of this process involving 2-3 meters of slip movement in the upper scarp area and large lateral movements in the slope toe at river involving a few tens of meters and completely damaging the village living on it. It got reactivated by the flooding and land creep is still active.

This study attempts to reconstruct the geomorphologic evolution of the landslide from its initial state to present condition with a laser scan Digital Surface Model, detailed engineering geological map, cross sections, soil laboratory tests and satellite based Synthetic Aperture Radar processing. The map delineates two main landslide blocks, several sub-blocks, compressional and extensional zones, and secondary failures in the deposit. The maps provide new insights into the kinematics, dynamics and evolution of the slide. The patterns of movement and the landslide geometry are studied to understand the likelihood of a rapid, catastrophic failure causing landslide dam and further damaging the road and village.

The evolution of Kimmantung Cliff

*** Keng-Hao Kang [1], Ming-Wan Huang[2], Shun-Hsing Yang[3], Yii-Wen Pan[1], and Jyh-Jong Liao[1]**

[1]*Department of Civil Engineering, National Chiao Tung University, Taiwan*
[2]*Disaster Prevention and Water Environment Research Center, Taiwan, National Chiao Tung University, Taiwan*
[3]*Central Region Water Resources Office, Water Resources Agency, Ministry of Economic Affairs, Taiwan*
**Corresponding author: kangkanghk@gmail.com*

The Kimmantung Cliff is located at the Yushan National Park Batongguan area, Taiwan. It has been marked on the map of Yushan National Park over one hundred years. Headwater erosion makes the landslide area keep expending. Then, the headwater erosion may affect the safety of the trail of Yunshan to Batonguan Trail. Multi-staged stereoscopic pairs of aerial photographs from 1980 to 2010 were used to understand the geomorphology and identify the slope failure area. Field investigation was conducted to investigate the attitude of slaty cleavage and joints around Patungkuan area. The Patungkuan area belongs to the headstream of the Laononchi River. The aerial photographs show that the adjacent region displays trellis drainage pattern. On both sides of the stream, relicts of old topographic surfaces, and rounded and curved hills are preserved. In the broad and flat grassland of the Patungkuan area, the up-stream of these old stream channels points towards the Kimmantung Cliff. It is obvious that the up-stream of the Chenyulanchi River is also the up-stream of the ancient Laononchi river. Due to recent tectonic uplift and the more rapid up-stream erosion, the headwaters of the Laononchi River were captured by the Chenyulanchi river, so that the increased up-stream area would supply larger quantities of water to the Chenyulanchi river. Consequently, rapid headwater erosion and stream incision along the joints and slaty cleavage causes the Kimantung Cliff expanding. The expanding rate of the Kimantung Cliff is estimated 3.2 m/yr to the west and 1.4 m/yr to the north approximately, but it may not affect the safety of Yushan to Batongguan Trail so far.

A complete watershed monitoring system in ShengMu village, Taiwan

***Ko-Fei Liu, and Shi-Shao Wei**

Department of Civil Engineering, National Taiwan University, Taipei, Taiwan
**Corresponding author: kfliu@ntu.edu.tw*

To under the complete sediment transport process in a watershed is always a challenge to researchers. During a rainfall event, it starts with landslides and then material from slides can stay near the slides, turn into debris flows or become part of river sediments. Where and when these processes occur are difficult to simulate and almost impossible to predict. One of the reasons is that there is no such data that cover the whole process. This research is to find a proper location and install all the necessary monitoring equipment. A nonstop monitoring process will be performed and data will be available for interested researchers. Then all analyzing tools for monitored data will be available for researchers from all over the world.

There are other field monitoring stations (Iverson, 1992; Badoux, 2009). But there has no location designed as watershed monitoring area. The target area for such a monitoring system is Shenmu Village in Nanto County, Taiwan. The watershed has 5,777 ha, 87.75% of the total area, with slope greater than 40%. Only 41 ha area has slope less than 5%. Elevation goes from 981 m to 2862 m. There were 12 debris flows observed at Shenmu area of Nantou County, Taiwan between 2004 and 2014. Huge areas (312.2 ha) with continuous landslides were also recorded within two sub watersheds. The sediments production is estimated to be 1,829,830.67 m^3/yr. The annual outflow of sediments is 353,803.65 m^3. It shows that this area is an idea place for studying sediment transport over slope land. Therefore, it is planned by water and soil conservation bureau in Taiwan to establish an international research center in this area.

The monitoring network is planned for this area. The data monitored includes satellite and aerial images, EM wave, sound wave, rainfall, flow rate and other factors related to sediment transport. Key locations for monitoring station and equipment are planned. To insure the data collected are meaningful and useable, data cross checking process is imposed. The available methods for analyzing data are provided. All equipment calibration method in the field or in standard lab is designed to ensure the quality of monitored data.

The rainfall warning system is put into test on this site. Warning systems with geophone and video cameras are also planned to be tested as long with the display of analyzed data such as velocity, predicted location of debris flows or grain size distribution etc.

REFERENCES

Badoux, A., Graf, C., Rhyner, J., Kuntner, R., McArdell, B.W., 2009, A debris-flow alarm system for the Alpine Illgraben catchment: design and performance. Nat Hazards, v. 49 (3), pp. 517–539.

Iverson, R.M., Costa, J.E., and LaHusen, R.G., 1992, Debris-flow flume at H.J. Andrews Experimental Forest, Oregon. USGS Open-File Report, pp. 92-483.

A conceptual model of geomorphological evolution in a gigantic paleo-landslide site

Ting-Hua Wei, Yen-Chieh Huang, *Kuo-Wei Li, Yii-Wen Pan, and Jyh-Jong Liao

Department of Civil Engineering, National Chiao Tung University, Hsinchu, Taiwan
**Corresponding author: KWLi@nctu.edu.tw*

A Large-scale landslide may result in significant casualty and facility/property damage. A catastrophic large landslide is often with a deep-seated failure surface and with large volume. Exploring the possible evolution of a large paleo landslide can be beneficial for better understanding of the landslide stability at present, and may be helpful for the prediction of the potential slope failure in the future. A site in Luchang (in the Miaoli County, Taiwan) is taken as a case study for studying the geomorphological evolution of a high-relief-mountain slope subjected to very large paleo landslides. The rock formation of this site is Miocene sedimentary rock composed of very thick sandstone and shale. An anticline structure and two inactive faults are present in the studied region; the anticline axis extends approximately along the crest of the mountain. The rock strata dip towards the primary slope direction so that plane sliding is kinematic admissible before the paleo landslides occurred. This high-relief slope contains obvious scarps near the crest as well as wide and thick (over 100 meters) colluvium. These features strongly indicate that large-scale landslides likely had occurred in the past. Beginning with a comprehensive site investigation, this study constructed the present geological model of the studied area at first. A conceptual model of geomorphological evolution was then proposed. Accordingly, the evolution model was examined for its admissibility of kinematics and stability through a sequential series of stability analyses and run-out simulations. The conceptual model assumes that the slope had a convex landform originally. The slope experienced a couple times of large plane failure and their resulting run out, which were probably triggered by extreme events of rainfalls or earthquakes. As the scarp finally retreated to the anticline axis, the plane-sliding mechanism of slope failure turned into rock falling. Eventually, the slope turned to its current landform. The evidence of the evolution sequence can be supported by the talus below the scarp and the colluvium retrieved from boreholes.

LEM analysis and mitigation suggestions of Rangvamual landslide along NH-54, Aizawl, North-East India

Lal Dinpuia

Department of Geology, Pachhunga University College (Mizoram University), Aizawl, Mizoram, India
E-mail: dinpuiageo@gmail.com

Rangvamual landslide is situated at the western limb of the Aizawl Anticline along NH-54, the State lifeline and Lengpui airport road. It coordinates between 23°44'59.88" and 92°41'40.24" at about 805 m amsl and falls under the toposheet no. 84A/10 of the Survey of India. The landslip surface covers an area of 15,316.4 m^2. Landslide experienced in the area after slope modification for building construction followed by rainfall on June and September in 2014. One Assam type building was collapsed and one RCC building (Cold Storage Building) was affected. One post of 132 kV power line connecting western towns of the state was also distorted, and frequently interrupting the traffic for more than 2 years. The landslide can be classed as 'debris slide and earth slide' of translational type. Removal of debris and construction of gabion walls were undertaken only after two years without detailed geological studies. Proper mitigation measures are suggested (Fig. 1) after geotechnical and LEM analyses.

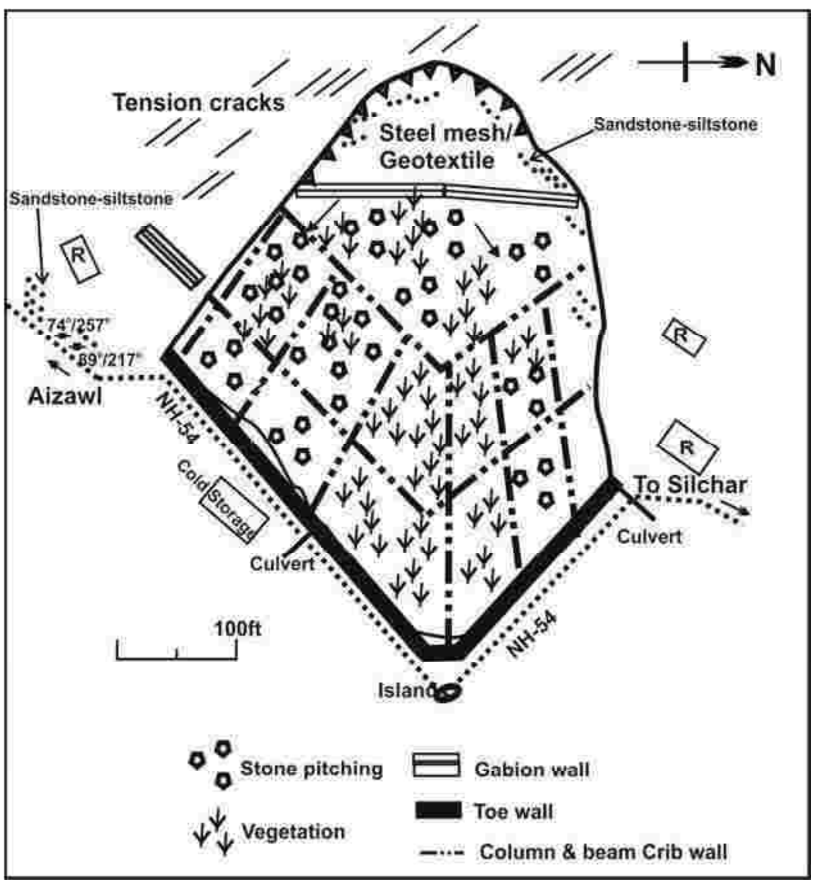


Fig. 1, General geology and mitigative suggestions for Rangvamual landslide along NH-54

Geological investigation and monitoring of Ramhlun Sports Complex landslide, Aizawl, Mizoram, North-East India

Lal Dinpuia

Department of Geology, Pachhunga University College (Mizoram University), Aizawl, Mizoram
E-mail: dinpuiageo@gmail.com

Aizawl city is one of the most landslide prone cities in India. Landslides mostly occurr during monsoon season. The Ramhlun Sports Complex is situated at the eastern flank of the Aizawl anticlinal ridge (Fig. 1). Landslide that took place on August, 2012, had affected 16 houses. The landslide was triggered by incandescent rainfall receiving 1746.50 mm. Again, in August 2013, numbers of tension cracks were observed in area after 1521.80 mm rainfall. Consequently, 38 houses were dismantled and collapsed. This incidence affected 195 persons from 41 families. A geological investigation was then performed, and representative soil samples were analysed for determining Atterberg's limits, California Bearing Ratio (CBR), optimum moisture content (OMC) and maximum dry density (MDD). The rate of movement was monitored from 3rd July 2015 up to 14th August 2016 by tape extensometer (SIS-400) and crackmeter (SIS-201). The width of tension cracks are also monitored and measured using Vernier Caliper. The study concludes that the area is unsafe for settlement and unsuitable for construction of pavement/link road and other infrastructure works.

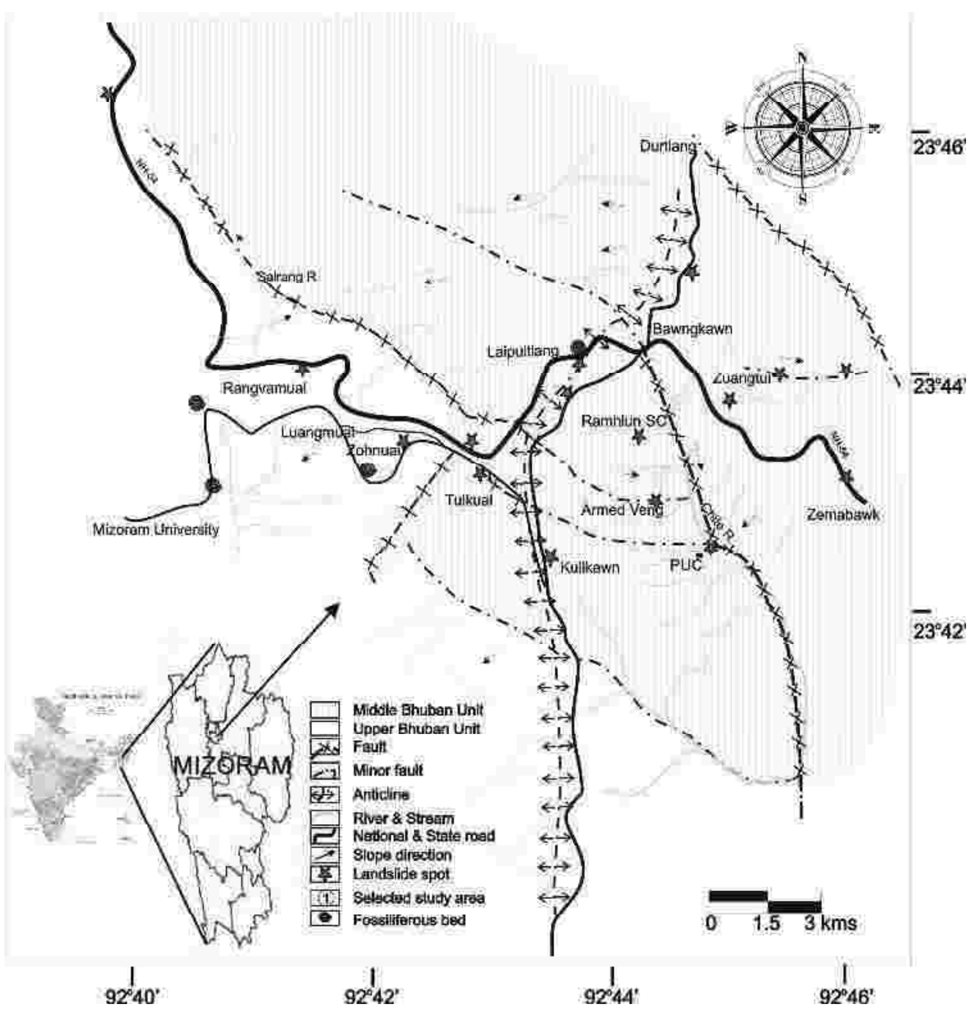


Fig. 1, Location map of Ramhlun Sports Complex, Aizawl

Rainfall failure mechanism of bedding Slope with inclined argillic interbeds

***Li Long-qi[1,2], Ju Neng-pan[1,2], Deng Tianxin[1,2], Yanbin Jiang[1,2], and Zhang Shuai[1,2]**

[1]*State Key Laboratory of Geohazard Prevention and Geoenvironment Protection, Chengdu University of Technology, Chengdu, Sichuan 610059, China*
[2]*College of Environment and Civil Engineering, Chengdu, Sichuan 610031, China*
**Corresponding author: Wangys60@163.com*

With the increasing occurrence of storm rainfall, various bedding rock slopes produced in the mountainous areas of western China. Field investigation shows that the distribution of argillic interbed played an important role in the failure of bedding rock slope, while the influence of it on the bedding rock slope is not still thoroughly known to engineers. In the present study, four experiments, including a slope with a high inclined argillic interbed (HI slope), a slope with double inclined argillic interbed (DI slope), a slope with a high horizontal argillic interbed (HH slope), and a slope with double horizontal argillic interbed (DH slope), were conducted by considering the number and inclination of argillic interbed in a bedding rock slope with a slope angle at 35° under a rainfall intensity of 1.38 mm/min. A monitoring system, including 9 displacement gauges and 6 pore pressure sensors, has been set in the slope model (Fig. 1) to monitor the real-time response of 4 kinds of slopes. The results show that the largest displacement occurs in the DI slope, whose value is 240 mm after 12 hour of continuous rainfall. The slope with horizontal argillic interbed is prone to have high position landslide, and the failure zone area of the DH slope is about 3 times larger than that of the DI slope during one rainfall. The pore pressure at deep the DH slope, the HH slope and the HI slope in decreasing order. Meanwhile, the failure type of the HH and the DH slope is progressive while that of the HI and the DI is abrupt. This study can provide some advice to design and monitor of similar slopes.

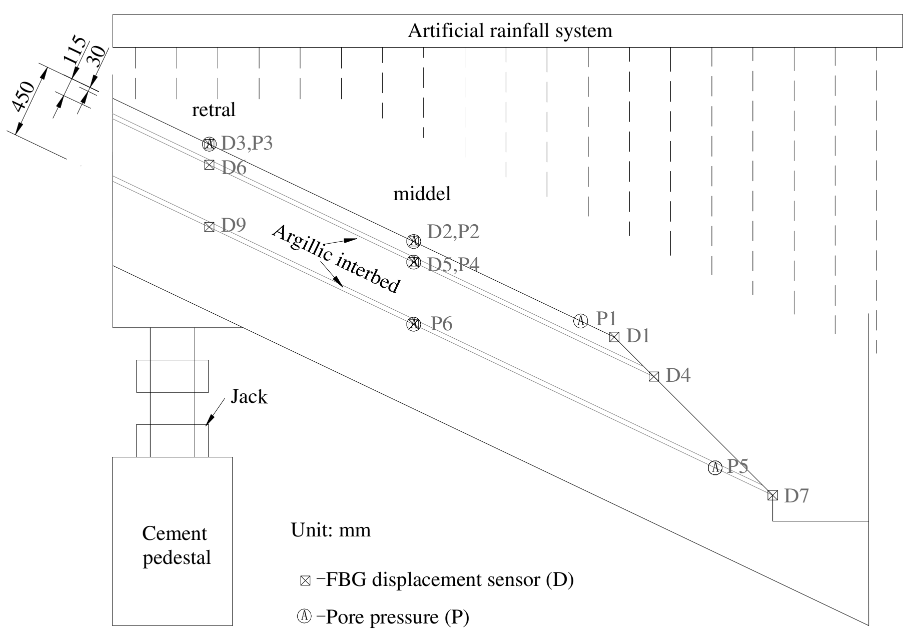


Fig. 1, Sketch Map of the model and layout of diverse sensors

Study on coarse soil of Chenjiaba Landslide by ring-shear test

***Lina Ma[1,2], and Shengwen Qi[1]**

[1]*Key Laboratory of Shale Gas and Geoengineering (KLSGG), Institute of Geology and Geophysics, Chinese Academy of Sciences, Beijing , China*
[2]*University of Chinese Academy of Sciences, Beijing , China*
**Corresponding author: 1571122655@qq.com*

The Chenjiaba Landslide is a typical long-runout landslide. It is significant to research on its mechanism of high-speed and the evolution process about landslide material during the motion of landslide. A series of ring-shear tests were performed by ring shear apparatus on the coarse soil of the Chenjiaba Landslide under different size range (0.075–5 mm) and different normal stress (50 KPa, 100 KPa, 150 KPa and 200 KPa), in which the maximum shear displacement and shear rate were 795 mm and 0.55 mm/s. The test results indicate that the coarse particles are squeezed, rolled and rearranged during the shear process, resulting in the fluctuant and wavy curves between shear stress vs. shear displacement. With the increase of normal stress, the wave tends to be strengthened. Then, some datum and graphs show that there are particles crushing during testing. It demonstrates the process of fine grading. Especially, the average particle size of the first group decreases from 1.1 mm before shearing to 0.59 mm after shearing. In the later stage of landslide, these soil materials get squeezed and crushed, tending to be fine, and gradually forming sliding zones. In this process, the friction coefficient gradually reduces (cohesion dropped from 16.7 KPa to 10.95 KPa, and friction angle dropped from 31.9 to 27.3 degrees), therefore most of these soil materials can move on the sliding zone rapidly and remotely. The residual strength does not tend to be stable, but always remains wavy. Therefore, there are some non-negligible errors for coarse soils to obtain residual strengths.

Landslide hazard mapping using limit equilibrium method with GIS application of roadway traversing mountain slopes: Case of Kitaotao Bukidnon, Philippines

***Ma. Catherine Q. Arca, and Glen A. Lorenzo**

Graduate School of Engineering, Mindanao State University- Iligan Institute of Technology, Iligan City, Philippines
**Corresponding author: cathiearc1580@gmail.com,*

Landslides in mountainous terrain often occur during or after heavy rainfall, resulting in the loss of life and damage to the natural and/or built environment. Mapping or delineating areas susceptible to landslides is essential for land-use activities and management decision-making in mountainous areas (Dai and Lee, 2001). Furthermore, individual slope failures are generally not so spectacular or so costly as earthquakes, major floods, hurricanes, or some other natural catastrophes. Yet, they are more widespread, and over the years may cause more property lost than other geological hazard. In many developing regions slope failures constitute a continuing and serious impact on the social and economic structure, of which the true measure is not in monetary units but rather in disruption and attendant misery of human lives (Varnes, 1984).

This paper presents the application of limit equilibrium method (LEM) in landslide hazard zonation mapping at the national highway section of the Municipality of Kitaotao along the Davao City route, Philippines as shown in Fig. 1. This route plays a vital role in the transport of goods and services in the region. However, this national highway is prone to rainfall-induced landslides. Records show that almost every year this highway is being disrupted by landslide, in which traffic flow disruption due to the subsequent road clearing would take several hours or even up to several days. A total of eighteen (18) test pits were excavated for soil sample collection and 60 probe holes were drilled using bucket augers to determine the soil thickness above the potential sliding/failure plane. The soil thicknesses data gathered were correlated to the slope angle in order to determine the spatial distribution of soil thickness in the study area. The geotechnical properties of these soils were evaluated and used in the slope stability analysis using Bishop Simplified Method through Geoslope (Slope\W) 2016 software. GIS software spatial analyst was used to map the calculated factor of safety (FS) under semi-saturated and fully saturated conditions. The values of factor of safety were group into different stability classes in order to develop the landslide hazard zonation map. The landslide hazard zonation map revealed that geology 1 and 3 are more prone to landslide with FS values within the range of 0.5-1.25 and degree of stability of low to very low. This present study generated a new, improved and localized landslide hazard zonation mapping reflecting the factor of safety that can be readily used in engineering works.

REFERENCES

Dai F.C. and Lee C.F., 2001, Landslide characteristics and slope instability modeling using GIS, Lantau Island, Hong Kong. Elsevier Online, v. 42, pp. 213–228. https://doi.org/10.1016/S0169-555X(01)00087-3

Varnes, D.J., 1984, Landslide hazard zonation: A review of principles and practice. A review of principles and practice. United Nations Educational, Scientific and Cultural Organization (UNESCO), France. Online, pp. 9–63. http://unesdoc.unesco.org/images/0006/000630/063038EB, pdf.

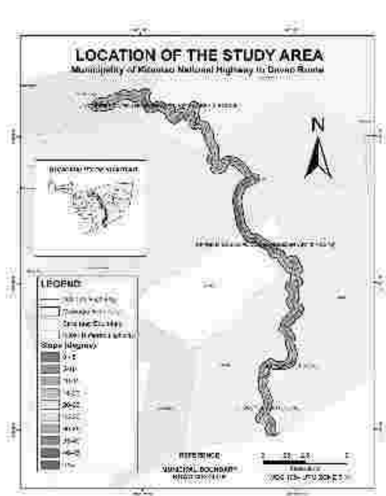


Fig. 1, Location of the study area

Landslide EVO: an interdisciplinary citizen science research project to build resilience against hydrologically induced landslides and floods in mountain regions of Nepal

***Madhab Uprety[1], Sumit Dugar[1], Jonathan D. Paul[2], Wouter Buytaert[2], Megh Raj Dhital[3], Puja Shakya[1], Bharat Raj Pant[3], Amrit Dhakal[3], and Landslide EVO Team**

[1]Practical Action Consulting South Asia, Kathmandu, Nepal
[2]Department of Civil and Environmental Engineering, Imperial College London, UK
[3]Department of Geology, Tri-Chandra Multiple Campus, Tribhuvan University, Nepal
**Corresponding author: madhab.uprety@practicalaction.org.np*

Whilst landslides and floods are frequent phenomena across the mountainous landscape of Nepal, the scientific understanding about the driving processes behind these hazards is limited. The underlying complexities in hydro-geological processes and sheer difficulties in their continuous monitoring have made these disaster-prone regions hugely data scarce. Underpinned by the weak disaster risk governance structure and the majority of the vulnerable population being under poverty, the local resilience of mountain communities also tends to be low and often decreasing over time. Therefore, generating site-specific scientific information on landslides and floods with local buy-in and linking them to local and regional risk governance structures could enhance disaster resilience in these regions.

Recent advances in in-situ and remotely sensed monitoring, risk modelling and forecasting, vulnerability assessment, and polycentric risk governance have provided opportunities to implement the evolving concept of citizen science (Buytaert, 2014) for improved understanding of disaster risks in data-scarce mountain regions. Emerging open source and cloud-based risk analysis platform scan support the de-centralized data processing workflow and networks for developing polycentric early warning systems. Linking data analysis platforms to social computer networks and ICT (e.g. mobile phones, tablets)could furthermore allow tailored interfaces and people-centered decision and policy-support tools to be built, which can effectively support a polycentric approach towards information provision and communication incontext of disaster risk reduction and resilience building (Paul, 2017).

Within the Landslide EVO Work Packages (Fig. 1), we leverage recent technological and conceptual advances in environmental data collection, processing and communication to deliver an end-to-end polycentric early warning and policy support system for hydrologically induced landslide and floods hazards across western Nepal. Using cost-effective sensor technology, we will implement grass-roots monitoring of precipitation, river flow, soil moisture, and landslide morphology. Using these data, meteorological extremes, and their impact on spatiotemporal patterns of landslide risk across the Karnali Basin (Fig. 2) will be analysed. Combining community-based rainfall data merged with satellite products, this project will develop high-resolution maps for extreme precipitation and river flow triggers. Community-based mapping of landslide risks and vulnerability will be complemented by remotely-sensed and model-based landslide risk mapping. We will also exploit the recent development of Environmental Virtual Observatories (EVOs), which are open and decentralized, allowing information to flow freely between multiple actors.

Overall, we aim to develop and demonstrate an operational landslide early warning system both at the basin scale and community level, and integrate it with the existing flood early warning system, thereby supporting the concept of multi-hazard early warning system for Nepal.

REFERENCES

Buytaert W., Zulkafli Z., Grainger S., Acosta L., Alemie T.C., Bastiaensen J., De Bivre B., Bhusal J., Clark J., Dewulf A., 2014, Citizen science in hydrology and water resources: opportunities for knowledge generation, ecosystem service management, and sustainable development, Frontiers in Earth Science, 2, 26.

Paul, J.D., and the Landslide EVO Team, 2017, Citizen science for hydrological risk reduction and resilience building, Wiley Interdisciplinary Reviews: Water, In Press. doi: 10.1002/wat2.1262

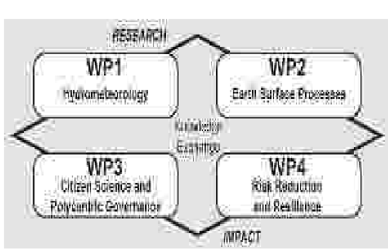


Fig. 1, Landslide EVO Work Packages

Fig. 2, Geographical Scale of the Landslide EVO

Engineering geology of old rock topple-wedge slide, Malekhu Area, Central Nepal, Lesser Himalaya

***Mahesh Raut, and Naresh Kazi Tamrakar**

Central Department of Geology, Tribhuvan University, Kirtipur, Kathmandu, Nepal
**Corresponding author: Mahesh.raut1218@gmail.com*

A huge landslide was identified on the right bank of the Malekhu River at about 1 km upstream from the Malekhu Bridge of the Prithvi Highway, and was named Malekhu Landslide (Tamrakar et al. 2013). The landslide area consists of quartzite with sericite partings, chlorite schist and amphibolite of the Robang Formation of the Kathmandu Complex. Currently, the authors discovered the additional western portion of the landslide, which extends through the boundary between the Robang Formation and the Malekhu Limestone upto the upper part of the Malekhu Limestone located just for about 50 m upstream from the old Malekhu Bridge. This upper part of the Malekhu Limestone consists of siliceous dolomites and phyllite.

The landslide extends for about 800 m along the Malekhu River valley slopes having the maximum relative relief of about 70 m. The newly discovered 400-meters long western portion of the landslide out of the 800 m length showed toppled structure while the eastern 400-meters of the landslide showed toppling and wedge sliding. The toppling in this massive landslide is old however the wedge sliding is reactivated one occurring at different portions of the massive landslide especially in the eastern part. Therefore, geomechanical properties of rock masses of the landslide slopes were assessed for Rock Mass Rating (RMR), discontinuity and finally Slope Mass Rating (SMR).

The toppled blocks had rotated from its right side up position to the current position by 36 degrees. The bed dip direction had also rotated about 31 degrees from the major dip direction of toppling. The rotation perhaps occurred during sliding of the toppled blocks. The toppling phenomenon is a flexure toppling of passive mode. The landslide is complex and old in which the wedge failure is reactivated during the April 2015 earthquake in Nepal. Many Tension cracks were found on the crown of the landslide. Currently, the wedge failure is active.

The landslide area shows fair rock to good rock categories based on RMR. According to SMR evaluated, the eastern portion of the landslide is completely stable whereas the central portion is partially stable to complete unstable. The western portion is partially stable. The kinematic analysis shows that the toppling is stable whereas sliding of the toppled blocks and wedge failure modes are unstable due to presence of potential wedges. There is a possibility of failure of the central slope along the SW direction. Since the roads, settlements and a community water tank, which are located in the crown of the landslide, are in risk and there are continuous stresses of seismic vibration and river toe cutting during flash flooding, it is urgent to monitor and mitigate the Malekhu Landslide.

REFERENCES

Tamrakar, N.K., Singh, J.L., Bista, K.K., and Maharjan, P., 2013. Toppling and wedge failures in Malekhu River area, Malekhu, Central Nepal Lesser Himalaya. Bulletin of the Department of Geology, Tribhuvan University, Kathmandu, Nepal, v. 16, pp. 21–28.

Climate change, natural hazards and potential impacts on infrastructure development: focus on the dry, northern Himalaya (Mustang District, Nepal)

Monique Fort

Université Paris Diderot, Sorbonne-Paris-Cité, CNRS UMR 8586 Prodig,
E-mail: fort@univ-paris-diderot.fr

In the Himalaya, the consequences of climate change are a fairly debated issue, with different outcomes depending on the type of primary data and scaling methods utilized, and the areas considered. In the northern side of the Himalaya, glaciers decline, their consequences on natural hazards and water resource, have been of great concern in the last decades. Precipitation nature (rainfall, snowfall), amount (<300 mm/a) and seasonality were also considered, with more uncertainty in their evolution hence in their impacts. Other parameters such as ground ice, were less considered; yet in the upper Himalayan valleys they might be significant and affect local infrastructure. We focus on the Mustang district (Nepal), where a new road has been recently open to traffic up to the northern Tibet-China border. At the northern transition with monsoon environments, the area is characterized by a semi-arid, continental climate, with sharp contrasts between valley bottoms (<2000 m) and high, glaciated peaks (up to >8000 m), Settlements are located on quaternary terraces, along valleys and at river junctions, mostly relying economically on irrigated crops, trade and tourism.

Natural hazards induced by climatic change may appear in different ways. (1) Despite limited glacial cover, the possibility of glacial outburst floods may again occur from the Man Shail similarly to the devastating one of the late 1980' (2) Increasing ground instability is also expected along north facing, shaley slopes (namely in the vicinity of Muktinath), hence triggering earth flows and occasional debris flows activity that might affect the new road and associated growing settlements (3) Rock avalanches induced by permafrost melting of the steepest cliffs (i.e. >7000 m Nilgiri north face) may also impact the tributary valleys floors and Kaligandaki (see ≈1000 yr-old rock avalanche remnants between Jomsom and Tukuche) (4) Water availability in the near future is more difficult to predict, due to glacial retreat and to possible change in the spatial influence, intensity and timing (onset and duration) of the monsoon precipitation, all parameters poorly constrained by the models. Any change in precipitation amount may affect groundwater reserves, hence springs discharge (5) The combination of higher snowfall and rapid melting may also favor the occurrence of destructive flash floods/debris flows (Fig. 1), with direct impacts on irrigation canals and fields, road infrastructure and villages (e.g. Lupra, Marpha). Eventually, the overall potential increase of natural hazards and geodisaster management should be anticipated when planning new infrastructure and will require a careful maintenance to keep the good connection of these upper valleys with Pokhara (the second largest city of Nepal).

Fig. 1, Debris flow, Lupra valley, and its destructive impacts at the Kaligandaki junction

Rainfall induced landslides, west coast of India

R. Nagarajan

Center of Studies in Resources Engineering, Indian Institute of Technology, Bombay, India
E-mail: rn@iitb.ac.in

Rainfall induced landslides are prevalent in the west coast of India, that receive south west monsoon rainfall during June to September. Rainfall observation stations report couple of daily events exceeding 200 mm/day. Monthly maximum rainfall is reported during July and August. This study examines the spatial distribution of rainfall and reported events. It is found that orographic rainfall aids in the triggering of slides. 3 cumulative and daily rainfall events show positive correlation with the reported events. Rainfall intensity / amount is highest at rain gauge stations located at coastal and plateau regions. It is recommended that in addition to daily rainfall, 3 days cumulative rainfall should be considered in the landslide vulnerability analysis and warning system.

Residual-state shear creep tests in a modified ring shear machine and numerical modeling for failure prediction

***Netra Prakash Bhandary[1, 2, 3], and Ryuichi Yatabe[3]**

[1]*Faculty of Collaborative Regional Innovation, Ehime University, Matsuyama, Japan*
[2]*Graduate School of Science and Engineering, Ehime University, Matsuyama, Japan*
[3]*Center for Disaster Management Informatics Research, Ehime University, Matsuyama, Japan*
**Corresponding author: netra@ehime-u.ac.jp*

This study is basically related with the creeping type large-scale landslide behavior, in which landslides mostly exhibit extremely low displacement rate (i.e., a few centimeters to a few decimeters per year). Use of ring shear machines in measuring landslide material strength and studying landslide displacement behavior has been in practice for several decades, but creep tests in shear using a ring shear machine to study landslide creep behavior is still in preliminary stage (Bhat et al., 2013a, 2013b; Bhandary et al., 2014). Creeping landslides exhibit large displacements before they completely fail or collapse, which means the sliding surface material of most such landslides may be considered to be in residual state of shear, which is ideally a state at which the shear strength of material is generated out of truly frictional resistance between the platy clay particles.

While landslide creep behavior may not be well understood through conventional creep tests, it is expected that residual-state shear creep tests in a modified ring shear machine may consolidate the understanding of creeping behavior of large-scale landslides. In this study, we first conduct a series of ring shear tests followed by residual-state shear creep tests on artificially prepared clayey materials using a modified Bishop-type ring shear machine. Then, based on the test results obtained from the experimental study, a numerical model for failure prediction in residual-state shear creep is developed taking into account a combination of Kelvin's (Voigt's) creep model and Maxwell's relaxation model together with a slider element. The test results reveal that the residual-state creep failure takes place only under a creep loading ratio of unity or greater, and that every soil material exhibits a certain amount of displacement (i.e., critical displacement, δ_c) beyond which the failure accelerates leading to complete collapse regardless of the loading ratio as indicated in Fig. 1 (upper). R_{rcs} in Fig. 1 represents residual-state creep stress ratio, which is a ratio of applied shear creep stress to residual strength of the clay material. The critical displacement is found to be dependent of the shear characteristics of the soil material.

Fig. 1 also compares the data obtained from experimental study and from numerical model. There is certain level of similarity and an acceptable level of agreement in the experimental data and predicted data, but the model still needs modification and improvement. In this numerical model, the state controlling parameters, such as shear modulus and coefficient of viscosity, were determined on the basis of the experimental results. So, in this study the numerical model of residual-state creep failure is considered to be only a preliminary model, which needs to be generalized further in the days ahead. This study is expected to help predict landslide failure under an ideal condition (i.e., residual state of shear and no effective stress changes) of landslide creep.

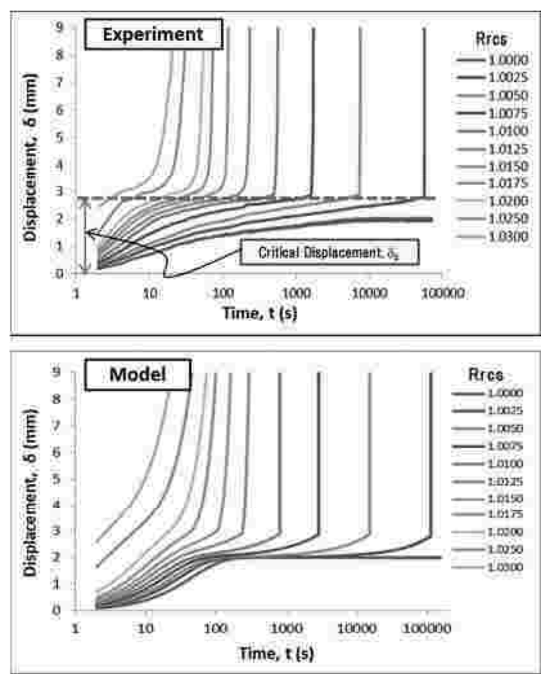


Fig. 1, Comparison of experimental and numerical model predicted data of residual-state shear creep tests on sand powder (75%) and bentonite (25%) mixed sample

REFERENCES

Bhandary, N. P., Bhat, D. R., and Yatabe, R., 2014, Understanding Large-Scale Landslide Displacement Behavior Through Residual-State Creep Shear Tests in a Modified Ring Shear Machine, Proc. 12th International Symposium on Geo-disaster Reduction, B. Tiwari et al. (eds.), USA, pp. 32–41.

Bhat, D. R., Bhandary, N. P., Yatabe, R., 2013, Residual-state Creep Behavior of Typical Clayey Soils, Nat. Hazards, v. 69(3): pp. 2161–2178.

Bhat, D. R., Bhandary, N. P., Yatabe, R., 2013, Method of Residual-state Creep Test to Understand the Creeping Behavior of Landslide Soils. Proc. The 2nd World Landslide Forum, Landslide Science and Practice, C. Margottini et al. (eds.), Springer Berlin Heidelberg, v. 2, pp. 635–642.

FEM-based stability analysis of Jure landslide slope in Nepal

***Netra P. Bhandary[1, 2, 3], Ram C. Tiwari[1], Ryuichi Yatabe[3], Sanjay K. Jha[4], and Nijjal Shrestha[4]**

[1]Faculty of Collaborative Regional Innovation, Ehime University, Matsuyama, Japan.
[2]Graduate School of Science and Engineering, Ehime University, Matsuyama, Japan.
[3]Center for Disaster Management Informatics Research, Ehime University, Matsuyama, Japan
[4]MSc in Geo-Technical Engineering, Institute of Engineering, TribhuvanUniversity, Nepal.
**Corresponding author: netra@ehime-u.ac.jp*

In this work, we carry out a finite element method-based stability analysis of Jure landslide in Sindhupalchwok district of Nepal (Location: 27°45'N to 27°46'N Latitude, 85°51'57"E to 85°52'38"E longitude; Altitude: 800m at raod base to 1650m at crown top), which occurred in August 2014 killing more than 150 local people and destroying many local settlements and infrastructures. The study area comprises hill slopes along a road stretch of 1.1km along the Araniko Highway from Chainage 83+400 to 84+500. The analysis was done for different landslide slopes with availability of failure slope geometry and soil profile. The FEM slope models were prepared and displacements on different strength reduction factor values were computed (Fig. 1). Mohr-Coulomb failure criterion along with strength reduction method was employed to analyze the slope (Matsui and Sam, 1992). Residual cohesion intercept values of soil layers and corresponding values of internal friction were obtained from lab tests. Back analysis was done to correct the data by taking constant cohesion value obtained from the lab tests (Table 1). The validation of the work was done with LEM-based program 'Slide' and also from the literature. As a result, satisfactory results and correlations were obtained. Then, a mitigation model was prepared based on factored safety factors (Table 2) based on Popescu (2001).

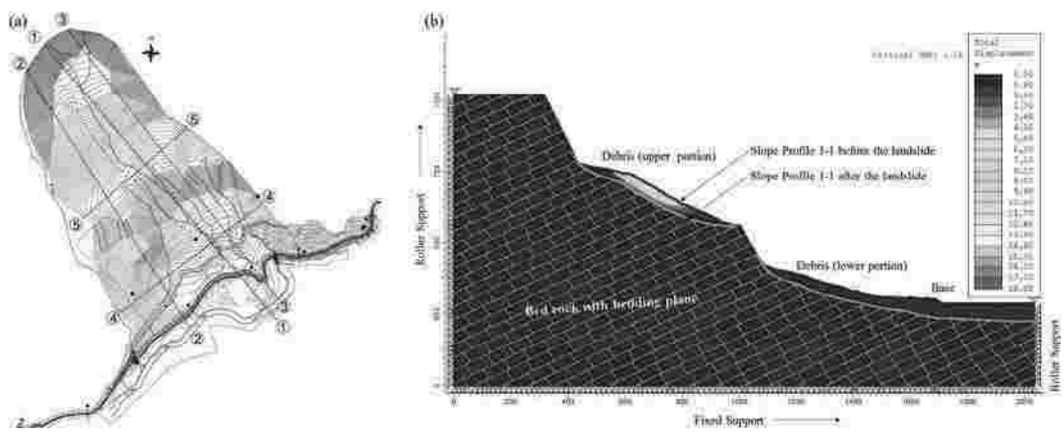


Fig. 1, Typical numerical model of Jure landslide slope: (a) Contour map of the study area and (b) Computational results of total displacement (m) at Profile 1-1(Mid Profile) of Jure landslide area along with modeling details in Rocscience Phase2 framework

Table 1: Material model for the slope stability analysis.

Material model for soil slope stability

Material: Disintegrated debris, slope Failure Criteria: Mohr-coulomb, Unit weight=18-21.7 kN/m^3, Elastic Properties (Griffiths and Lane, 1999), Modulus of elasticity=105 kPa, Poisson ratio=0.3, Shear parameters (from lab test): Cohesion (peak)=5-6.75 kPa and Angle of friction (peak)=28.55-32°

Material model for rock slope stability

Material: Schist inter bedded with Phyllite, Failure Criteria: Generalized Hoek and Brown, Unit weight=29kN/m^3, Elastic properties such as Modulus of elasticity, Modulus of elasticity of intact rock=54000000 kPa, Poisson ratio: 0.3, Intact rock uniaxial compressive strength: UCS=80000 kPa, GSI=60, mi=7 and Disturbance factor D=0 (No blasting). Joints: Basic friction angle (φb)=20°, Roughness angle (i)=15°, Joint normal stiffness=0.1 GPa/m and Joint shear stiffness=0.01 Gpa/m.

Table 2: Computational results of the landslide slope stability analysis along with the correlation of the FEM results with LEM.

Stability analysis at different soil slope condition	Phase2 (FEM) Slope stability analysis result at 3 sections (CSRF)			Slide (LEM) result of section 1 (CSRF)	
GWT position	1	2	3	Ordinary/Fellineus	Janbu
Dry	1.16	1.02	1.00	1.17	1.17
WT at 100m from the	1.00	0.62	1.00	0.94	0.97
WT at 200m from the	1.00	*NC	1.00	0.85	0.96
WT at 300m from the	0.94	*NC	0.99	0.83	0.91
WT at 400m from the	0.39		0.49	0.38	0.42
WT at 500m from the	0.35		0.38	0.34	0.37
WT at surface	0.15		0.25	0.25	0.27

REFERENCES

Matsui, T. and Sam, K., 1992, Finite element slope stability analysis by shear strength reduction technique, Soils and Foundation, v. 32(1), pp 59–70.

Popescu, M. E., 2001, A Suggested Method for Reporting Landslide Remedial Measures. IAEG Bulletin, v. 60(1), pp. 69–7.

Conceptual design of Ie - Motobu subsea tunnel, Okinawa, Japan

***Ömer Aydan[1,2], Naohiko Tokashiki[3], and Koichi Suzuki[4]**

[1]*University of the Ryukyus, Department of Civil Engineering, Nishihara, Okinawa, Japan*
[2]*Disaster Prevention Research Institute for Islands Region*
[3]*Research Institute of Crustal Engineering and Disaster Prevention, Japan*
[4]*NPO, Green Earth, University of the Ryukyus Nishihara, Japan*
**Corresponding author: aydan@tec.u-ryukyu.ac.jp*

Okinawa Island is one of the major islands of Ryukyu Archipelago and it is the highly populated and is one of the most famous tourist spots in Japan. The Naha airport is now expanded to deal with the congested air traffic and the Self-defense Airforce of Japan also uses the airport. On the hand, the northern part of Okinawa Island including Motobu Peninsula has no airport although many hotels and sightseeing places are in Motobu Peninsula.

Ie Island is about 5 km from the Motobu Peninsula and it has an airport with a runway with a length of 1500 m, built in relation to the 1975 Ocean Expo. The biggest city is Nago in northern part of Okinawa Island and it is only accessible from Naha airport, which is about 70-90 minutes by car. The Churaumi Aquarium, Ocean Expo Park and other related touristic spots are about 2 hours distance from the Naha airport. Therefore, the utilization of the airport together with some extension of the runway and the construction of terminal facilities and its connection to Motobu Peninsula would definitely shorten the access time and vitalize the economy of the northern part of Okinawa Island and nearby islands such as Sesoko and Ie. Although the construction of a bridge between Ie Island and Motobu Peninsula has been considered, the depth of the seabed and distance make the bridge construction not feasible. Furthermore, the bridges are quite vulnerable to bad weather conditions such as typhoons, which may them useless during the strong winds and poor climatic conditions.

The first author has been involved with the construction of the subsea tunnels in Istanbul Strait between Asia and Europe. This led the author to consider the construction of a subsea tunnel, which would not be affected bad weather conditions. The authors have done some explorations on the geological conditions and seabed topography along the possible route. Although there is yet no boring data along the possible route, the anticipated geological formation is likely to be chert, which outcrops at Bise-zaki shore of Motobu Peninsula and Ie Island (Fig. 3). The top surface of the chert formation is slightly covered by Ryukyu limestone. Nevertheless, the subsea tunnel is expected to be located in the chert formation if it is situated 20 m below the seabed. It would be quite desirable to situate the tunnel in rock mass so that strong ground motions would not affect the tunnel during earthquakes. The depth of the tunnel would be about 90 m below the mean sea level. The required lining thickness would be only 30 cm even the uniaxial compressive strength of concrete is chosen to be only 30 MPa using thick-wall cylinder concept (Fig. 4). Therefore, the construction of the tunnel should be quite feasible and the access between Motobu and Ie Island would be possible any time. Furthermore, the tunnel together with extended airport facility would be also quite useful in case of natural disasters.

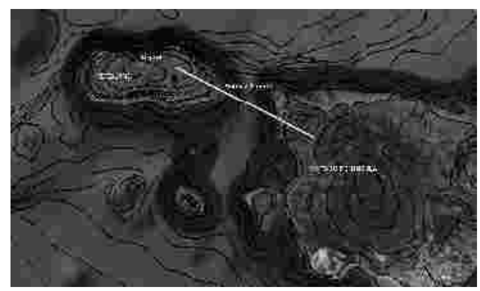


Fig. 1, Surface and seabed topography and proposed alignment of the subsea tunnel (base-map from Google-Earth)

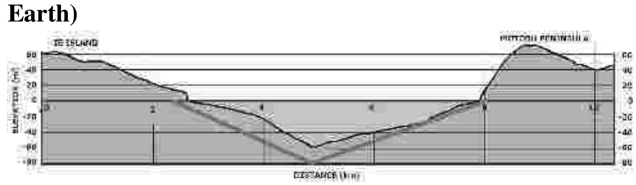


Fig. 2, Longitudinal cross section along the alignment

Fig. 3, A view of chert formation at north shore of Ie island

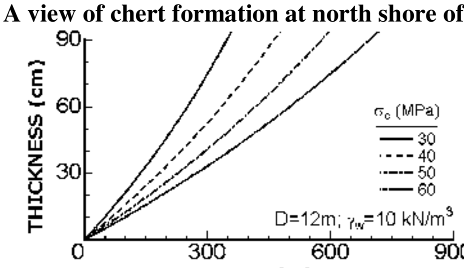


Fig. 4, Required lining thickness as a function of depth

REFERENCES

Google Earth, 2017, Satellite base map.

The Clarence landslide triggered by the 2016 Mw7.8 Kaikoura earthquake, New Zealand

***Peng Guo, Ren-mao Yuan, Zhu-Jun Han, and Hong-liu Ra**

Institute of Geology, China Earthquake Administration, Beijing, 100029, People's Republic of China
**Corresponding author: 1143916106@qq.com*

The large-scale landslide near the fault is generally closely connected with the movement pattern of seismogenic fault. Understanding the relationship between landslide and distribution characteristic and kinetic property of the seismic fault is of great scientific and practical significance for predicting landslide occurrence and disaster assessment. The 2016 Mw7.8 Kaikoura earthquake killed two people and triggered more than tens of thousands of landslides over a total area of about 10,000 km^2, with many buildings and infrastructures damaged. A large landslide was induced by the earthquake on the right bank of the Clarence River, distributing near the footwall of the Papatea seismic fault (42°9'43.07"S, 173°52'9.83"E). It provides favorable conditions for us to research the relationship between the landslide and the seismic fault because of the particular tectonic location of the Clarence landslide. The comparison and analysis of remote sensing images before and after the earthquake and field investigation reveal that (1) the shape of the landslide is typical, and the sliding surface is continuous on the whole, with its dip angle decreasing from sliding zone to depositing zone; (2) the landslide develops near the paleo-landslide area located at the slope of the mountain composed of limestone, with back wall, scarp and landslide body of the paleo-landslide identified easily; and (3) the Papatea fault in the Clarence region is characterized by thrust-dominated movement with the displacement as high as several meters, and the seismic surface rupture zone is so complicated that is manifested as a vertical deformation zone with a width of ~90-170 m. Based on the above findings, we propose an evolution model to explain the triggering mechanism and formation process of the landslide. The paleo-landslide firstly provides a potentially dangerous landslide body and sliding surface for the landslide area. When the earthquake occurs, the obvious thrust movement of the Papatea seismic fault produces a certain width of the rock deformation and fracture zone near the top of the landslide area located at the footwall, and consequently the slope of the landslide area suddenly increases. Long periods of the shaking, intense seismic acceleration and the rapid vertical displacement of the seismic fault result in the tensile stress of the rock fracture zone increasing sharply. Accordingly, it starts to slide along the potential sliding surface on the condition of the slope becoming steep suddenly. The sliding striations, visible clearly from the back wall of the landslide show that there is a significant shear effect between the bottom of the landslide body and the sliding surface, indicating that the landslide slides eastward as a whole. But the sliding direction turns to be NE-NEE because of the high terrain of the south and lower part of the landslide. The landslide is mainly featured by deceleration and deposition process when reaching the ground surface. Therefore, in addition to geological and geomorphologic conditions and local seismic acceleration, deformation distribution characteristic and movement property of seismic fault could also play an important role in the occurrence of earthquake-triggered landslides.

Landslide susceptibility assessment of the Chure Khola catchment area of the Siwalik region, Central Nepal

***Prakash Gyawali[1], and Naresh Kazi Tamrakar[2]**

[1]Ministry of Irrigation, Singhadurbar, Kathmandu
[2]Central Department of Geology, Tribhuvan University, Kirtipur, Kathmandu Nepal
**Corresponding author: gyawali317@gmail.com*

Landslide susceptibility analysis was carried out in the Chure Khola catchment, between Amlekhganj and the Churia Mai area of the Bara District, covering 20 sq. km area. The catchment lies in the Siwalik Hills composing the Siwalik Group of rocks of Late Miocene to Early Pleistocene age. Owing to the week and fragile geology, the Siwalik Hills are prone to the gully erosion, shallow landslide and debris flow, during the heavy rain storms in monsoon seasons. In the present study landslide susceptibility assessment was carried out using two methods, rapid field assessing and statistical index methods. For the susceptibility mapping of the river bank slope of the Chure Khola and the Bhedi Khola, field based method was used. The seven parameters such as slope angle, slope material, reduction to groundwater, effect of drainage, effect of past failure, effect of vegetation cover and effect of land use were used to calculate factor of safety in the field, and the slope areas were classified as highly susceptible (FS<0.7), susceptible (0.7<FS<1), marginally stable (1<FS<1.2) and stable (FS>1.2) categories. Finally, a susceptibility map was prepared. For the total 4.179 sq. km area, the areas covered by highly susceptible, susceptible, marginally stable and stable zones are respectively 21.56%, 22.11%, 17.37% and 38.95%. Among the highly susceptible and susceptible zones identified, 71% sites have experienced recent slope failures. Landslide susceptibility mapping of the whole catchment area was prepared using statistical index method. For this seven causative parameters such as elevation, slope, slope aspect, curvature, river proximity, stream density and lithology were determined and prepared from DEM using Arc GIS. Eighty percent landslides were used as the training sample for the spatial analysis, whereas 20% landslides were used for the validation of the study. The landslide susceptibility map exhibits the areas covered by very high, high, moderate, low and very low susceptibility zones are 47.18%, 25.28%, 19.77%, 3.60% and 4.16%, respectively. Validity of the study was determined using Riemann Sums method. Success Rate Curve shows that 78.04 % of the areas lie under the curve. Evaluating susceptibility in small watershed is important to mitigate shallow landslide related problems and in rehabilitating forest area in the Chure Hill regions of Nepal.

Surface deformation monitoring and potential landslides detection in loess area based on Unmanned Aerial Vehicles UAV

***Qiang Xu，Yuanzhen Ju，Dalei Peng，Xiujun Dong，and Xing Qi**

State Key Laboratory of Geohazard Prevention and Geoenvironment Protection, Chengdu University of Technology, Chengdu 610059, China

**Corresponding author: xuqiang_68@126.com*

The technology of Unmanned Aerial Vehicles (UAVs) carrying a multitude of external instruments has been applied in wide fields such as agriculture and forestry, environment, mapping, geology and culture heritage protection. In recent years, more and more researchers utilized the UAV photogrammetric technology to complete the landform measurement and the deformation observation of the landslides. The Heifangtai is located in Gansu Province of China. It is a loess table land which has an area of 11.5 square kilometers. Since 1960s, the groundwater level in the tableland has obtained a continuous increase due to the agricultural irrigation, which causes the landslide events frequently occurring at the edge of the tableland with a total of more than 120 times. Herein, the high-precision aerial images of the Heifangtai loess tableland was obtained with the aid of the UAV photogrammetric technology. Through analyzing the aerial images at different times, the detailed deformation information at the edge of the loess tableland can be extracted, the zones with the potential sliding in the future can be delineated, and thus the early identification of the loess landslides can be realized. First of all, the high resolution images were obtained by the UAV for the whole table land with geographical coordinates. In order to improve the resolving accuracy, fourteen primary control point and nearly one hundred ground control points was set up in the table land, and their coordinates were gained by the Global Position System (GPS) and Real Time Kinematic technology (GPS-RTK). Based on the coordinates of control points, the areal images were resolved with very high precision. The point cloud, the three-dimensional model and the orthograph of the tableland have a centimeter-level in horizontal direction and a decimeter-level precision in vertical direction. Though the elevation difference analysis of the Digital Elevation Model (DEM) of the tableland at different times, the spatial deformation zones of the tableland and the detailed deformation features of subzones can be clearly delineated. Then, the zones with potential sliding risks within a period of time in the future can be predicted. The UAV deformation measurement demonstrates a good agreement with results of the GPS monitoring, fissure measurement and the field survey, and provides a new way to carry out the regional ground deformation monitoring and the early landslide hazard identification.

Climatic investigation using short ice cores from Kazbek and Elbrus

***Aleksandra Khairedinova, Stanislav Kutuzov, and Vladimir Mikhalenko**

Institute of Geography, Russian academy of Sciences (IG RAS), Moscow, Russia
**Faculty of Geography, Moscow State University, Moscow, Russia*
**Corresponding author: khaisasha_@mail.ru*

Ice cores studies are the key to the understanding of the past climate. Using the isotope, chemical, radioisotope and other analyses of glacial ice cores we may reconstruct the air paleotemperatures, accumulation value, atmospheric composition and other parameters. Combination of various methods permits reconstructing paleoenvironment, The aim of our study was the analysis of shallow ice cores for assessing the environmental conditions in the Caucasus mountains. The current level and changes in natural and anthropogenic aerosol concentrations were determined, the data on microparticle content was interpreted as well as those on the isotopic composition of snow-firn cores and the atmosphere.

The chemical composition of short glacial ice cores drilled in high mountains of Kazbek and Elbrus was analyzed. From the comparison of mean annual concentrations of major ions in the Kazbek and Elbrus ice cores, the similarity of the absolute values of some cations (K^+, Li^+) was found, despite the difference in the sampling elevation above sea level. Much higher mean annual concentrations of ammonium ions were revealed for the Kazbek Mount as compared to the Elbrus Mount. The analysis of backward trajectories of air mass flows showed that the Middle East and the north Africa are the main sources of aerosol input to the Caucasus.

Landslide susceptibility zonation in Sidamukti, Majalengka, West Java, Indonesia

***Rachma Nurul Ajrina[1], Qhonita Anif Febian[1], and Ilham Prasetya[2]**

[1]*Undergraduate student of Geological Engineering Faculty, Padjadjaran University, Indonesia*
[2]*Geological Engineering Faculty, Padjadjaran University, Indonesia*
**Corresponding author: rachmanajrina@gmail.com*

Sidamukti area in Majalengka Regency, Indonesia is included into zone of medium-high level of land movement. However, the growing demand of housing has recently started to force urban population to settle on these prone-to-landslide areas. To limit hazardous potencies that might be resulted from this uncontrolled city sprawling, a study concerning a detail zoning of landslide potencies within Sidamukti area should be taken, and this study was conducted in accordance to that purpose. The soil's mechanical properties data were obtained from laboratory tests in which soil samples collected in field were used. Using computer software the landslide potencies were presented in the form of factor of safety. A zonation map of slope safety factor was produced. This map is expected to be used as reference of city development planning in Sidamukti.

Comparison of information value and weight of evidence models in landslide hazard assessment in Chure region: a case from Surkhet

***Radhika Maharjan, Subodh Dhakal, and Niraj Bal Tamang**

Central Department of Evvironmental Science, Tribhuvan University, Kirtipur, Kathmandu, Nepal
**Corresponding author: radhika.maharjan2009@gmail.com*

Landslides are the main natural hazard in Nepal due to its geological condition, continuous mountain forming process and diverse topography. Huge loss of lives and property due to landslides and flood is high in case of Nepal. Every year Nepal is facing problem related to landslide usually during monsoon season. Landslide hazard mapping is essential for the zonation of hazard prone areas. The landslide hazard maps are very useful for planning, development, and disaster management. In this study, the weights-of-evidence and information value methods were applied, within a geographical information system (GIS), to derive landslide hazard map of the Siwalik region of Nepal. Chhinchu watershed which lies in Surkhet District and also lies in Siwalik region of Nepal was taken as site for the hazard mapping and analysis. The main purposes of this study are to evaluate the predictive power of weights-of-evidence and information value methods for the landslide hazard assessment Siwalik region of Nepal and to illustrate relation between landslides and its triggering factors. Relevant thematic maps representing various factors (e.g. slope, aspect, elevation, plan and profile curvature, land use, geology and average rainfall from 1980-2016) that are related to landslide activity were generated using field data and GIS techniques. In order to validate the prediction model, landslides were overlaid over the landslide hazard maps and the areas of landslides that fall into each hazard class were calculated. The resulted landslide hazard value calculated from landslides data showed nearly 80% prediction accuracy by weight of evidence and only 65% prediction accuracy by information value method. The weights-of-evidence methods seem to have extensive applicability in Siwalik region of Nepal than information value method using these eight causative factors. And landslides triggering factors such as slope, aspect, land use, geology and rainfall had played significant role in causing landslides in Siwalik region.

Settlement of piles subjected to collapse of retaining wall

Rajesh Prasad Shukla

Department of Earthquake Engineering IIT Roorkee, Roorkee, India
E-mail: rpshukla.2013@iitkalumni.org

Pile foundation is commonly used in cases of large structural loading, unavailability of good soil at shallow depth and under various other adverse conditions. Piles supporting the loads coming from the soil are passive piles. Lateral loading is induced from the soil movement due to underground construction, landslides, tunneling, liquefaction, embankment loading and various other construction activities. The construction of retaining wall is to provide protection against landslides are very common. Structure supporting the soil can fail itself under certain circumstances, and under this condition an impulsive load is transferred from soil to piles. The collapse of retaining wall further affects the performance of other buildings and foundations resting in the vicinity of the failed retaining wall.

In this study, experiments were performed on small scale model piles to determine the settlement of pile foundations exposed to the movement of soil induced from collapse of a retaining wall. A wooden shutter, of five rotatable parts, was designed to simulate the collapse of retaining wall. Each of the part is connected through two 'but hinges' and these hinges allow each parts of shutter to rotate freely toward outside. Each of movable part is attached to two wooden columns separately by means of two bolts. Loosening of these two bolts allow each of rotatable part to fall individually without affecting the remaining lower parts. Both wooden columns were firmly attached to the tank wall using the nut and bolts. The settlement, lateral displacement and bending moment induced in piles were measured in testing. Embedment ratio and height of failed retaining structure are the two important factors affecting the behavior of piles significantly. Fig. 1 shows that settlement of pile groups of embedment ratio 20 decreases nonlinearly with increase in the distance.

The settlement is expressed in a dimensionless form as a ratio of pile settlement (S_t) to critical height (H_c) of the retaining wall. The confining pressure and soil-piles friction increases with increase in the distance (X) between pile and retaining structure and consequently, the settlement of piles decreases. The settlement of piles of embedment depth 20 reduces with increase in pile spacing. The variation in settlement of piles with spacing is presented in Fig. 2. The settlement of piles increases with the increase in height of retaining wall. In piles of embedment ratio 10, the settlement is increasing with increase in the spacing, and number of piles, while piles of embedment ratio 20 show the opposite behavior to the previous case.

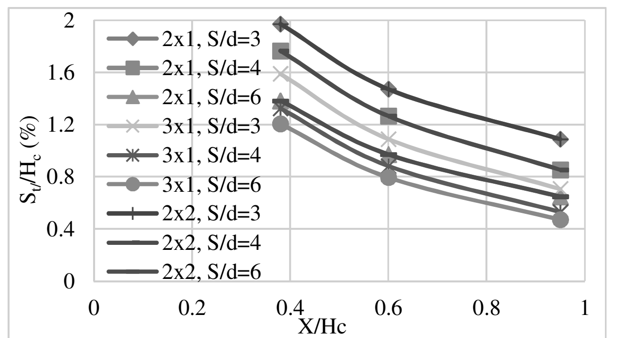


Fig. 1, Effect of distance between retaining wall and pile

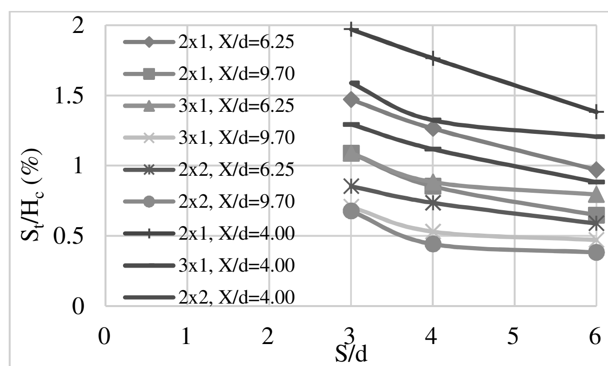


Fig. 2, Effect of spacing on piles settlement

In general, settlement of piles decreases with the increase in embedment ratio of piles group. Though settlement is increasing with increase in the height of collapsed retaining wall, effect is more significant in case of piles group of small embedment ratio. Results of study are limited to medium dense sand only.

The effect of slope inclination on seismic bearing capacity of footing resting near the slopes

***Rajesh Prasad Shukla, and Ravi Sankar Jakka**

Department of Earthquake Engineering, Indian Institute of Technology Roorkee, Roorkee, U.K., India, 247667
**Corresponding author:rpshukla.2013@iitkalumni.org*

In the hilly regions, footings are frequently constructed on or near the slope. The foundation resting over or near the slope lacks the soil support from the slope side which make its behavior very different from those of similar foundation on the level ground. Footing resting on slopes possess relatively lesser bearing capacity as compared to the footing on level ground. The bearing capacity further reduces under seismic loading.

In this study, an attempt has been made to determine the effect of slope inclination on seismic bearing capacity of footing. A 2D finite element analysis was used to model the problem. The pseudo-static method has been used to consider the seismic loading. The effect of various parameters, such as embedment of footing (D), angle of shearing resistance of soil (□), seismic loading has been also determined. The change in the soil deformation with slope inclination is presented for better understanding. A total of 7000 gauss elements were used in the domain. A typical model used in the analysis is shown in Fig. 1. The width of footing (B) is selected as 1 m.

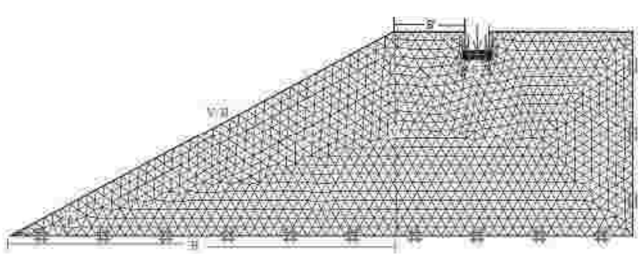


Fig. 1, A typical finite element model used in the study

Fig. 2 shows the effect of slope inclination on seismic bearing capacity. The result is presented for the setback distance of 7B. The seismic bearing capacity of footing resting on slopes is normalized with respect to seismic bearing capacity of footing resting on level ground and stated as bearing capacity ratio (BCR). Under the seismic loading, the bearing capacity reduces significantly and the reduction is relatively higher for seismic loading of higher intensity.

The effect of magnitude of seismic loading is presented in Fig. 3. The bearing capacity reduces with increase in the seismic loading. The effect of seismic loading is relatively significant in case of slopes of steep inclination.

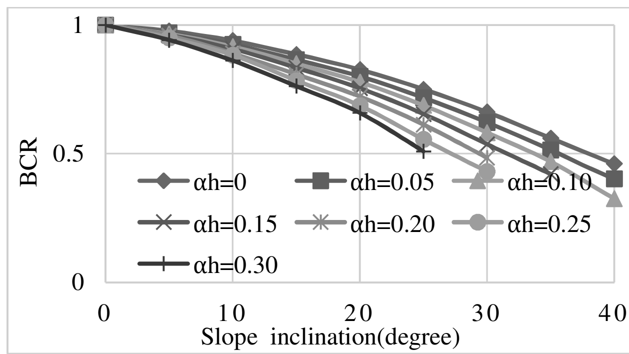


Fig. 2, Effect of slope inclination on seismic bearing capacity

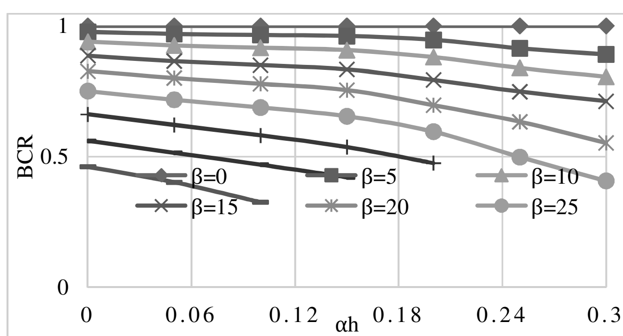


Fig. 3, Effect of seismic loading on seismic bearing capacity

Co-seismic large lateral earth slide associated with the 2016 Kumamoto earthquake Mw7.0 revealed from differential LiDAR DEM image analysis

***Sakae Mukoyama, and Tomoyuki Takami**

Kokusai Kogyo Co., Ltd., Tokyo Japan
**Corresponding author: sakae_mukoyama@kk-grp.jp*

After the main shock of 2016 Kumamoto Earthquake (Mw 7.3), not only seismic wide-area crustal deformation but also a lot of surface ruptures were observed around Aso Volcanic Caldera in Kumamoto Prefecture, Japan. In order to estimate ground displacements and deformation, we conducted Differential LiDAR DEM Image Analysis to measure ground movements. The data sets we used are 1 m mesh DEM (Digital Elevation Model) data measured in 2009 (pre-event) and in 2016 (4～30 days after the event). We applied the particle image velocimetry method for Digital Geomorphic Image Analysis(Mukoyama, 2011) on the calculation of 3-D vectors of ground displacements. This method has accuracy of 0.1m with sub-pixel interpolation.

As a result, seismic wide-area crustal deformation around caldera and displacements along the earthquake faults were observed (Mukoyama et al., 2017). These displacements indicate right lateral and normal motion of seismic-source-fault-model and were corresponding with the results of other field survey, the GNSS observations and D-InSAR analysis.On the other hand, large lateral slides of the area of 1-2 km diameter were observed in the area filled with unconsolidated lacustrine sediment on the caldera floor (Fig. 1). Amount of displacements of these area were 1-3 m. By the field survey, small horst and graben with open fissures and pull-apart basins were observed at the upper edge of the slid areas. In the lower marginal zone of the slid areas, some pressure deformations and damaged bridges and river embankments were observed. Additionally, hot-spring owners reported that some borehole casing pipes has deformed at the same depth of 50 m in the central part of slid area.

All of the observed data suggest that an area of more than 2 km of diameter and the 50 m of thickness slid in the NNW-direction over 1m (maximum 3 m). Interestingly, houses and architectural structures in entire town area on the moved block remained almost un-damaged, except buildings just on the ruptures. It is considered that liquefaction at the depth of 50 m by the main shock of earthquake increased pore pressure along the sliding formation, and caused large and slow lateral earth slide. However, these results require more detailed geological investigations for lateral sliding mechanism of particular bed.

REFERENCES

Mukoyama, S., 2011, Estimation of ground deformation caused by the earthquake (M7.2) in Japan, 2008, from the geomorphic image analysis of high resolution LiDARDEMs. Journal of Mountain Science, v. 8, no. 2, pp. 239–245.

Mukoyama, S., T. Sato, T. Takami, 2017, Estimation of coseismic surface displacement in the Aso-Caldera area before and after the 2016 Kumamoto Earthquake by topographical data analysis from differential LiDAR DEM, Report of the 2016 Kumamoto, Oita Earthquake Disaster Research Mission, pp.55–63.

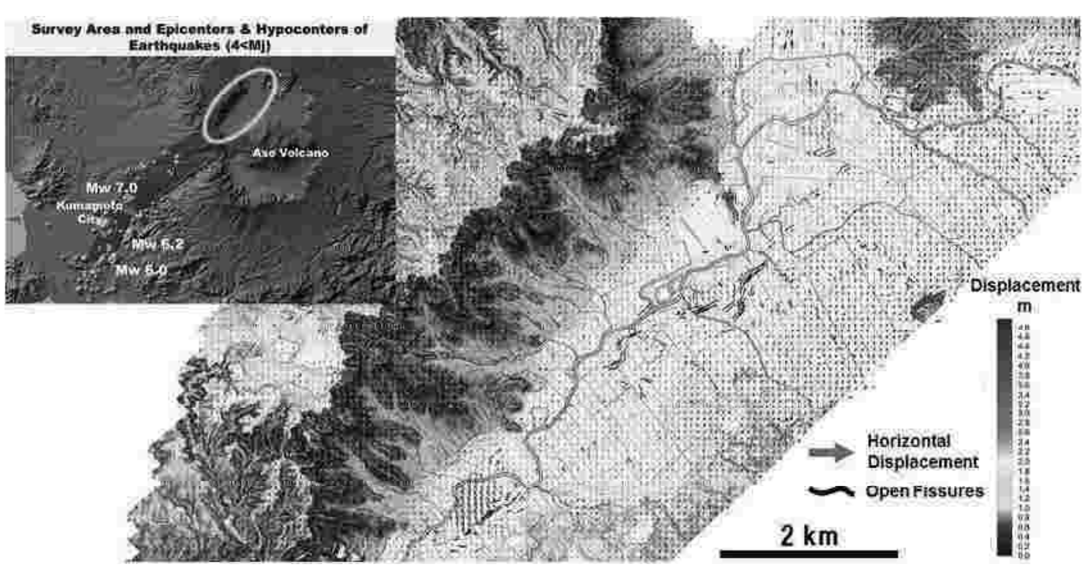


Fig. 1, Co-seismic large lateral earth slide in the caldera floor filled with unconsolidated lacustrine deposit

Deep-seated gravitational slope deformations in central Japan: their topographic features, development history, and relationship with the geologic structures

***Satoru Kojima[1], and Hidehisa Nagata[2]**

[1]*Department of Civil Engineering, Gifu University, Gifu 501-1193, Japan*
[2]*Fusuido Co Ltd., Obu474-0022, Japan*
**Corresponding author: skojima@gifu-u.ac.jp*

Recent developments of LiDAR techniques have made it possible to use accurate and reliable topographic maps in remote and inaccessible areas in Japanese mountains. Double (multiple) ridge(s) and uphill- and downhill-facing scarplets developed as deep-seated gravitational slope deformation (DSGSD) features are ubiquitous from high- (ca. 3,000 masl.) to low-altitude (ca. 1,000 masl) Japanese mountain ranges (e.g., Yagi, 1981; Kojima et al., 2015). The DSGSD topographic features became important for the mitigation of slope disasters, after the research by Chigira et al. (2013) that clearly showed the existence of DSGSD topographic features before the deep-seated catastrophic landslides in Kii Peninsula by the Typhoon Talas disasters in 2011. Development history and relationship with the geologic structures of the DSGSD topographic features, however, are unclear, because of scarcity of their basic data. The authors have been studying the DSGSDs during the last decade in Northern and Southern Japanese Alps (ca. 3,000 m asl.) and Mino mountains (ca. 1,000 m asl.), and report part of the results of the researches.

Double ridges and the sediments accumulated in the linear depression between them in the Mt. Kanmuriyama (1,257 m asl) area were examined geomorphologically, geologically, and geophysically (Kojima et al., 2015). Geomorphological studies in the field by using the topographic map made by 1 m-mesh LiDAR DEM (Digital Elevation Model) indicate that the double ridges are features of deep-seated gravitational slope deformation that the basement rock mass is sliding to the east by slumping. The basement rocks in this area are composed of Triassic chert and Jurassic sandstone generally trending WNW-ESE, and the depression between the ridges is filled with muddy sediments. We obtained cores of the sediments by hand-auger boring, the lithology of which is, from younger to older, alternating peat and carbonaceous mud, light gray sticky lacustrine (?) mud, and yellowish-brown mud and silt with basement rock clasts. The thickness of the sediments is 280 cm at maximum, and is thinning to the east, that is consistent with the formation model of the double ridges by the eastward slumping. The AMS-^{14}C ages of wood fragments and the ages of tephra sandwiched in the sediments clarified that the double ridge formed about 10 ka and has been stable until now, and that the average sediment accumulation rate is 0.25 mm/year. The electrical resistivity survey showed clear difference of resistivity at the boundary between the basement rocks and the sediments. The results of survey also indicate the existence of not only eastward sliding plane, but also westward sliding plane.

Detailed field geological mappings have been performed in the Tokugo-toge Pass (2,140 m asl.) and Mt. Chogatake (2,680 m asl.) areas in Northern Japanese Alps. The basement rocks in the area are composed of sandstone and shale with minor amount of chert of the Jurassic accretionary complexes, which generally trend NE-SW and dip moderately to NW. The major ridge trending NE-SW has asymmetrical slopes, namely steeply dipping SE ridge and gently dipping NW ridge. The difference results most probably from the well-developed bedding plane of the shale and sandstone; the NW slope is the dip slope, whereas the beds on the SE slope have the opposite dip. On the major ridges and gently dipping NW slopes there are many DSGSD topographic features such as double (multiple) ridge(s), uphill-facing scarplets, and linear depressions parallel to the trend of the ridges and the strike of the beddings, while along the NW-SE trending minor ridges few GSGSDs are recognized. The alternating beds of sandstone and shale near the surface have open cracks and show loosening and, in part, toppling structures, although the geologic structures in deeper part are invisible in the field.

The authors show the development history and the basement geologic structures of some DSGSD topographic features in central Japan, although the examples are limited. In the future, more case studies are needed not only in Japan but also in other mountain regions of the world.

REFERENCES

Chigira, M., Tsou, C.Y., Matsushi, Y., Hiraishi, N., and Matsuzawa, M., 2013, Topographic precursors and geological structures of deep-seated catastrophic landslides caused by Typhoon Talas, Geomorphology, v. 201, pp. 479-493.

Kojima, S., Kaneda, H., Nagata, H., Niwa, R., Iwamoto, N., Kayamoto, K., and Ohtani, T., 2015, Development history of landslide-related sagging geomorphology in orogenic belts: Examples in central Japan. In: Lollino, G., et al., eds., Engineering Geology for Society and Territory, Springer, v. 2, p. 553–558.

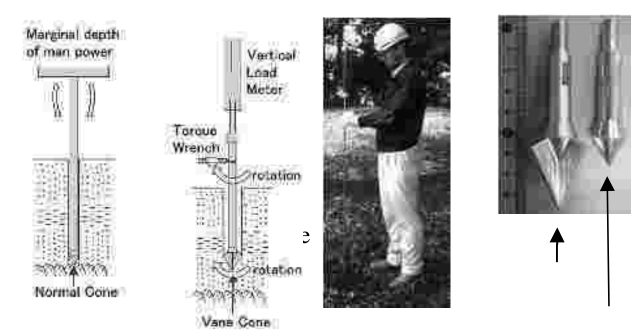
Yagi, H., 1981, The origin of uphill-facing scarplets distributed on the high mountain slopes of Japan, Geographical Review of Japan, v. 54, pp. 272–280 (in Japanese with English abstract).

A case study on in-situ shear strength measurement of topsoil and hazard evaluation of shallow landslides using soil strength probe

***Satoru Norimizu[1], Tetsuo Kanai[2], Ken-ichi Asai[1], Yoshinori Yajima[1], and Yasuhito Sasaki*[1]**

[1]Public Works Research Institute, Tsukuba, Ibaraki, Japan, [2]Oyo Corporation, Saitama, Japan
[1, 2] Research Group of Soil Strength Probe
**Corresponding author: geology@pwri.go.jp*

In Japan, many slope disasters on the road are caused by shallow landslides. It is necessary for making hazard evaluation logically to investigate topsoil thickness, cohesion (c) and angle of internal friction (ϕ). Therefore Soil Strength Probe (SSP; Fig. 1) was developed n order to measure above three data of soil (Sasaki, 2007). Topsoil thickness is measured out by static cone penetration testing (SSP with normal cone, ref. investigation.1/Fig. 1), and 'c' and ϕ by hybrid test of vane cone shear testing and vane shear testing (SSP with vertical load meter, torque wrench and vane cone, ref. investigation. 2/Fig. 1). A research group of SSP has been established in order to spread out SSP in public and study how to use SSP in-situ. This paper introduces two studies. The first is a comparison of 'c' and ϕ which are measured out by vane cone shear testing by SSP and triaxial compression test. The second is a case study of hazard evaluation of shallow landslides in-situ using SSP.



investigation.1 investigation.2 overview Normal cone

Fig. 1, Outline of Soil Strength Probe

The first study (Sasaki, 2010) shows eq. (1) in order to convert vertical forces measured out by SSP (Wvcin eq. (1)) into vertical stresses (σ in eq. (1)), and eq. (2) in order to convert rotated torque value measured out by SSP (Tvcin Eq. (2)) into shearing stresses (τ in eq. (2)). These equations are necessary to be more accurate by more tests.

$$\sigma \fallingdotseq 2.4\times10^{2}\,\mathrm{Wvc} \quad (\mathrm{N/m^2}) \qquad (1)$$
$$\tau \fallingdotseq 1.5\times10^{4}\,\mathrm{Tvc} \quad (\mathrm{N/m^2}) \qquad (2)$$

Fig. 2 shows the results of comparing vane cone shear tests and triaxial compression tests of soil samples. 'C' by SSP is a little bit higher than 'c' by triaxial compression tests (CUB). Therefore, it is necessary to decrease the figure of 'c' by SSP. On the other hand ϕ by SSP is almost equal to that by triaxial compression tests. But in some cases of results by SSP is a little bit higher than that by triaxial compression tests. The difference of test results is supposedly caused by soil variation. So it is necessary to study more about the layout and increase of testing places.

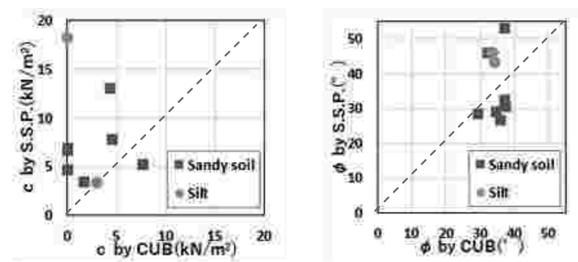


Fig. 2, Comparing SSP and triaxial compression tests

We investigated actual places of slope disaster (Nachikatsuura city, in Japan) and studied simple way of hazard evaluation of slope with SSP. The slope angle and topsoil thickness in near place of actual shallow landslides and non-collapse place, show that many landslides occurred in the area of thick topsoil and steep slope. The boundary of collapse and non-collapse almost is accordance with curved line of safety factor (Fs) = 1.0 on the assumption that 'c' is regarded as 4.7 kN/m^2, and ϕ as 34.5. This paper suggests how to evaluate slope stability by plotting the value of slope angle and top soil thickness measured out in-situ. This way of evaluation can specify rightly more than 90% of the shallow landslides. However, it regards more than 50% of the safety slope as unstable one. This misses-evaluation is caused by the supposition that the strength of sliding surface in-situ is fixed, although the actual field has various strengths of soil place by place and also on sliding surfaces. Therefore, it is very important to evaluate stability of slope in the place where the geologist considers that condition of topography and geology is similar in shape and quality.

REFERENCES

Sasaki, Y., 2007, Development of a simplified Soil Penetration Test for measuring shear strength of slope topsoil, Proceeding of the 6th Asian Regional Conference on Geohazards in Engineering Geology.

Sasaki, Y., 2010, Investigation manual about soil site of slope using Soil Strength Probe, Technical note of Public Works Research Institute, pp. 1–40. (in Japanese).

Slope stability in an expansive clay deposit from Regina, Saskatchewan, Canada

Rashedul H. Chowdhury[1], and *Shahid Azam[2]

[1]*Clifton Associates Limited, 340 Maxwell Crescent, Regina, SK S4N 5Y5, Canada*
[2]*Environmental Systems Engineering, Faculty of Engineering and Applied Science, University of Regina, 3737 Wascana Parkway, Regina, SK S4S 0A2, Canada*
**Corresponding author: shahid.azam@uregina.ca*

Geological origin, seasonal weather, and soil profile govern the shear strength of natural slopes. A glacio-lacustrine expansive clay deposit (up to 30 m deep) underlies the city of Regina, Saskatchewan, Canada. The deposit developed in the proglacial Regina Lake (fine particles settled during the Wisconsinan) from extensively eroded (alternate scraping, deposition, overburdening, and reworking of materials) glacial drift of the Quaternary period. Likewise, the area is characterized as *Dfb* (warm summers and continental climate) according to the Köppen climate classification system. The extreme seasonal weather variations include temperature that ranges from -14.7°C in January to 18.9°C in July and precipitation with 60% occurring between June and August while the remainder of the eight months is relatively dry. Finally, the soil profile in and around the city consists of high and steep valleys along the glacial melt water channels as well as low and gentle slopes due to typical glacial landforms such as moraines (raised ground) and eskers (a long winding ridge). The interaction of these factors result in the following phenomena in the expansive clay deposit: (i) alternate volume changes during summer (swelling due to raining and shrinkage upon evaporation); (ii) strain softening (loss of cohesion) due to cyclic winter freezing and spring thawing; and (iii) profile-dependant saturation and desaturation due to infiltration from the surface downward and capillary rise above the ground water table. The main objective of this research is to study the stability of slopes in the native expansive clay deposit. First, site investigations in and around the city will be carried out to determine typical slope profiles. Second, undisturbed samples will be retrieved from selected test pits for detailed laboratory investigations. Third, shear strength parameters will be determined under saturated and unsaturated conditions using the direct shear test. Fourth, parametric slope stability analyses will be conducted to determine the critical failure conditions using a computer model. This work will help in the design and construction of various types of civil infrastructure in the local expansive soil.

Climatic variations and 2017 short term rainfall induced Rangamati landslide disasters, Chittagong Hills Tracts, Bangladesh

***A. T. M. S. Hossain, and A. A. Mahadi**

Engineering Geology, Geotechnics and Geohazards Group. Department of Geological Sciences, Jahangirnagar University, Savar, Dhaka,, Bangladesh
**Corresponding author: shakhawathos2004@yahoo.com*

Rangamati is a hilly district in south eastern Bangladesh. Rangamati Hills are mainly composed of unconsolidated to poorly consolidated sedimentary beds of sandstone, siltstone and shales. It is a part of the Chittagong division and is bordered by the Tripura state of India to the north, Bandarban District to the south, Mizoram State of India and Chin State of Myanmar to the east, and Khagrachari and Chittagong Districts to the west. June 2017 landslide disaster is the worst in the country's history. This landslide was caused by an incessant downpour that began early morning of 12 June, dropping 343 mm of rain in 24 hours. On 13 June, 2017, heavy short term monsoon rain (Fig. 1) triggered a series of landslides and floods in Rangamati and other hilly districts of Bangladesh and killed more than 156 people, destroyed more than 5,000 houses and disrupted telecommunication, road networks and power lines(property loss of approx. $223 million). Deforestation in the area also contributed to the slope failures.

This research has evaluated the climate variability and its impact on the recent landslide hazards of Rangamati using last 30 years rainfall data and landslide events. From the analyses, it is established that highest amount of rainfall occurs during monsoon period of each year (June to September) and lowest during winter period (December to February) of each year. Annual rainfall trend of Rangamati is found to be an increasing trend of about 0.002 mm/year. From the monthly variation of rainfall data, it is observed that maximum rainfall occurs in monsoon period and the minimum rainfall occurs in post monsoon and winter period. Every year during monsoonal rainfall, landslide hazards kill many people in the hilly towns of Bangladesh including Rangamati. It is established that rainfall pattern can significantly influence on the landslide hazard events. It is also observed that short term high intensity rainfall is the major cause of shallow landslides due to weak and loose nature of the soils of the investigated area. Development of pore water pressure (PWP) within soil mass is also evaluated as discussed by (Tsaparas et al., 2002; Hossain and Toll, 2013). It is also observed that if small amount of antecedent rainfall for few days is added with huge amount of total rainfall for a single day, it may also contribute to the slope failures of the Rangamati area. To minimize the loss due to this disaster, proper actions should be taken immediately by the concerned authorities to save lives and properties of the investigated area under the current threat of climate change for sustainable development of Bangladesh. Preparation of landslide susceptibility map of each hazard prone area, geotechnical instrumentations, monitoring slopes, development of early warning system for landslide hazard forecasting, installation of more automated weather stations (AWS) are essential to control this hazard. In addition to these, other geological engineering mitigation measures must be taken immediately to control this hazard of Rangamati area of Bangladesh to reduce the future loss under the current change of climate.

REFERENCES

Hossain, A.T.M.S. and Toll, D.G., 2013, Climatic Scenario and Suction controlled Rainfall Induced Landslide Hazards in some Unsaturated Soils of Chittagong, Bangladesh, I3CIA-2013 Book, Publisher: AHDPH, pp. 851–859. ISBN: 978-984-33-7884-2.

Tsaparas, I., Rahardjo, H., Toll, D.G. and Leong, E.C., 2002, Controlling parameters for rainfall-induced landslide, Computers and Geotechnics, v. 29(1), pp.1–27.

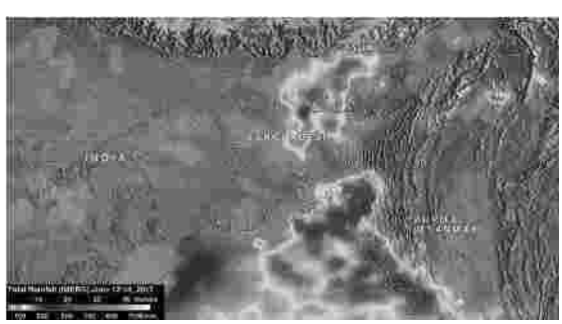


Fig. 1, NASA's IMERG Rainfall Map (12th to 14th June, 2017) Over 2017 Rainfall in the South Eastern part of Bangladesh

.

Horizonal drilling drainage as a preventive measure for water induced landslide risk reduction: a case study from Sindhuli Road section I, Nepal

***Shanmukhesh Chandra Amatya[1], and Mikihiro Mori[2]**

[1] *Nepal Landslide Society, Nepal*
[2] *Nippon Koei Co. Ltd. Japan,*
**Corresponding author: amatyasc@gmail.com*

Nepal is a mountainous country which covers about 77% area of mountain and hills with rugged topography and highly tectonized geology. Most of those areas are prone to sediment related water induced disasters such as slope failure, debris flow, and landslide which are triggered due to torrential rainfall during the monsoon rainy season, and that causes the loss of lives and properties, infrastructures and environmental degradation each year. The annual rainfall ranges from 2000 to 3000 mm (in the Central Region of Nepal). The natural disasters can not be prevented completely but efforts can be made for mitigating the impact of the disasters. Among the mitigation measures of water induced landslide disasters, the Horizontal Drilling Drainage Technology is one of the most effective countermeasures of landslide risk reduction. The main purpose of this technology is to release the pore water pressure in the landslide mass by reducing the groundwater level. The landslide disaster prone Kamala Mai Village area lies along the Sindhuli road section I, the National Highway, in Sindhuli District, Nepal which was generating subsidence and creeping of the road each year since many years back. This method was applied in the Sindhuli road Section I, Chanaige 29+300, Kamala Mai Village area. The result obtained from the application of the method shows an effective achievement to the Sindhuli road stability and the road users as well. Recommendation has been made to replicate the technology in other places of the country also in similar environment.

Structure effects of rock slopes under homogenous and dip bedded rock slopes shaking table tests

***Shengwen Qi[1], Zhifa Zhan[1,2], and Jianxian He[1,2]**

[1]*Key Laboratory of Shale Gas and Geoengineering, Institute of Geology and Geophysics, Chinese Academy of Sciences, Beijing, China,*
[2]*University of Chinese Academy of Sciences, Beijing, 100049, China,*
[*]*Corresponding author: qishengwen@mail.iggcas.ac.cn*

China is located in the Pacific seismic belt and the Himalaya seismic belt, where many earthquakes occurred in recent years. For example, Tens of thousands of seismic landslides were triggered by Wenchuan earthquake on 12th May, 2008 causing serious losses of life and property. Several post-earthquake investigations indicate that the slope structure plays a leading role in stability of rock slopes under earthquake. To study the structure effects of rock slopes, we conducted homogeneous rock slope and dip bedded rock slope shaking table tests in China Institute of Water Resources and Hydropower Research.

Based on the similarity theory and orthogonal test theory, barite powder, iron powder, quartz sand, gypsum and cement were chosen as similar materials to build the rock slope models. The two rocks slope models are 3.57 m long, 0.68 m wide and 1.20 m tall, the slope angle is 45°. Meanwhile, the bedding plane angle of dip bedded rock slope is 36º, the thickness of bedding plane is 15 cm. Through different input of horizontal sine harmonic wave loading, we found the seismic response characteristics of the two rock slopes showed obvious structure effects as following:

In the homogeneous rock slope, when the loading frequency was low (≤30 Hz), the horizontal amplification coefficient of PGA showed nonlinear amplification along the slope surface and reached the maximum at the slope shoulder, then decreased gradually. With the loading frequency increasing (≥45 Hz), the horizontal amplification coefficient of PGA showed nonlinear decrease and increased sharply at the slope shoulder.

In the dip bedded rock slope, it showed different seismic response regularities. When the loading frequency is less than 60 Hz, the horizontal amplification coefficient of PGA showed nonlinear amplification along the slope surface, but the maximum occurred below the slope shoulder and the monitoring point of PGA near the slope shoulder was also bigger than the slope shoulder, and then decreased. It was deduced that the bed plane at the slope crest caused this amplification phenomenon. However, when the loading frequency is near or beyond the model's natural frequency, the amplification phenomenon will no longer exhibit.

For the two slope models, the vertical amplification coefficient of PGA along the slope surface also showed differently. The amplification coefficient increased firstly and then decreased in the homogeneous rock slope, and the maximum occurred at the lower part of the slope. However, the amplification coefficient decreased monotonously before reaching the slope shoulder, and the maximum occurred behind the slope shoulder.

Characteristics of ground vibration signal produced by debris flows at Ai-Yu-Zi Creek, Taiwan

Shih-Chao Wei[1], *Ko-Fei Liu[1], Yi-Min Huang[2], and Yao-Min Fang[3]

[1]*Department of Civil Engineering, National Taiwan University, Taipei, Taiwan*
[2]*Department of Civil Engineering, Feng Chia University, Taichung 407, Taiwan*
[3]*GIS Research Center, Feng Chia University, Taichung 407, Taiwan.*
**Corresponding author: kfliu@ntu.edu.tw*

Ground vibration analysis can provide relevant information on the dynamics of debris flows or identification of flowing properties, and may allow timely warning for downstream villages. However, this issue is an inverse problem to interpret debris flow from ground vibration signal and it is restricted within limited field data. To analyze the seismic feature produced by real debris flows, the frequent debris flow site, Ai-Yu-Zi creek, was selected in this study. The Ai-Yu-Zi creek is located at Shenmu village, middle Taiwan with basin area of 405.02 ha and stream length of 3.731 km. The slope large than 55% is over 75% of basin area and the landslide ratio distinguished by satellite photos is increasing with year. The accumulated rainfall in rainy season (Apr-Oct.) and in dry season (Nov-Mar) are 2644.5 mm and 410.1 mm, respectively.

In Ai-Yu-Zi creek, the debris flows are observed at least 14 times during 2004 and 2017 in the Shenmu monitoring station built by Soil and Water Conservation Bureau (SWCB) in Taiwan. In this monitoring station, three geophones are buried in river bank to detect the underground acoustic signal of debris flow. Besides, two wire sensors and two video cameras are built for checking flow depth and front velocity. For signal processing, the amplitude method (Arattano, 1999), FFT, and time-frequency analysis are applied in recording signal generated by debris flows in past decade. The peak of amplitude level are checked with screenshot of video cameras and compared with spectrogram. Moreover, the superior frequency bandwidth is examined in different time segments such as before event or during event. The warning thresholds are also included in our discussion such as threshold in amplitude level and threshold in energy level integrated by superior frequency band width.

REFERENCES

Arattano M., 1999. On the use of seismic detectors as monitoring and warning systems for debris flows. Natural Hazards, v. 20, pp. 19–213.

Physical model experimental study of bank collapse in Three Gorges reservoir area under water level change condition

***Shuai Teng[1], Shimei Wang[1], Wenpeng Yu[2], and Peng Lu[2]**

[1]*College of Civil Engineering and Architecture,China*
[2]*Three Gorges University,Yichan,, Hubei,China*
** Corresponding author: 1028379178@qq.com*

Three Gorges Reservoir bank collapses frequently, endangering urban security and affecting the reservoir shipping. Therefore, through the on-the-spot investigation, for the soil slope which collapse most continually, the evolution process of the bank collapse under the condition of water level fluctuation was studied by physical model experiment. The bank deformation mainly occurred under the condition of water level descending. It gradually developed with the increasing of the water level fluctuation. During the first time water level descent, the middle-upper part of the slope appeared intermittent arc tension cracks (Fig. 1, crack 1 and 2) at the acting of the seepage force. As the second time water level decreased, the cracks expanded and connected. For the fourth time, the bank (Fig. 1) occurred slide and accumulation in the toe of slope, the slope angle was reduced. Following with the test, the deformation process would repeat. And the slope angle also became ever more gently. Eventually, the bank reached a new steady state.

Numerical simulation analysis results of the experiment show that the different directions seepage forces were produced in the process of water level fluctuation. During the rise of the water level, the seepage force in the slope pointed to the interior (Fig. 2), which was beneficial to the slope stability. But when the water level descends it pointed to the outward (Fig. 2), and became the principal failure factor. With the decreasing of water level, the water head difference gradually increased. The seepage force would rip the middle-upper part of the slope and continuing impact. Causing the crack to expand and bank collapse at the end.

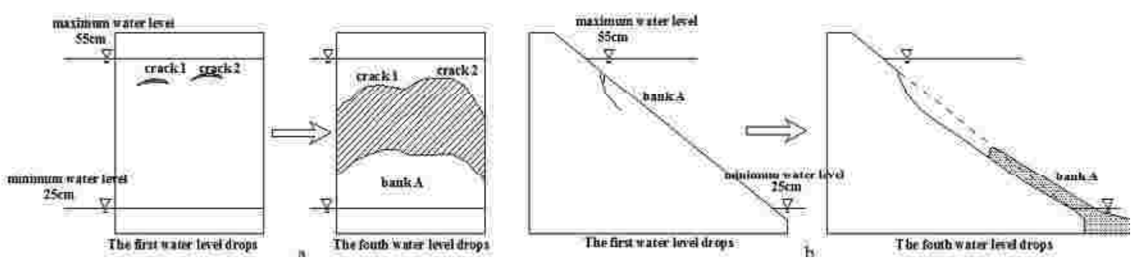


Fig. 1, The evolution process of bank collapse with the increasing of water level changes

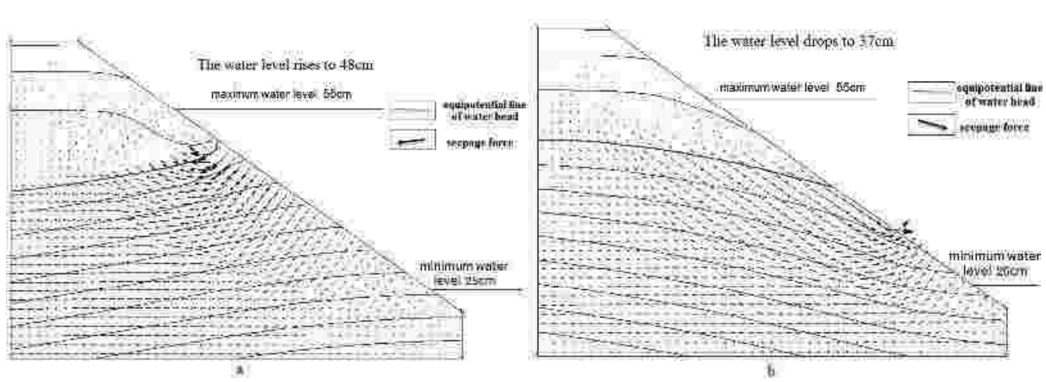


Fig. 2, Schematic diagram of seepage force during water level rise and fall

Dissection rate of landslide topography in Japan

Daisuke Kanbara[1], *Shuichi Hasegawa[2], and Makoto Yanagida[3]

[1]*Civil Engineering Division, Yonden Consultants CO., Takamatsu, Japan*
[2]*Department of Safety System Construction Engineering, Kagawa University, Takamatsu, Japan*
[3]*Geological Department, Hanshin Consultants CO, Tokyo, Japan*
**Corresponding author: hasegawa@eng.kagawa-u.ac.jp*

In Japan, landslides occur frequently and are distributed throughout mountain areas (as seen in the National Research Institute for Earth Science and Disaster Resilience landslide distribution map). Although landslides typically result from previously active masses that become reactivated, there are some which become stable and cause no damage to residential homes or roadways. Evaluating how these landslides were created and estimating the stability of present and future landslides is crucial in preventing potential disasters.

Ignoring landslides from historical records, it is difficult to approximate how long a landslide has been active or to estimate its active period. However, by comparing the ages found using ^{14}C dating on woodchips in landslides and analyzing the tephra that covers the landslide, it is possible to estimate the age. Using this method, some have reported landslides that date back to the late Pleistocene age (Ueki, 2005).

Estimating the age of landslides is beneficial for approximating when they will become active, studying their causes, and learning about their development. Therefore, to estimate the age of undocumented landslides, we focused on the landslides' degree of dissection.

In our study, we collected 58 landslide points with known age to the data. We examined their degrees of dissection with reference to previous research and accurately studied the association between degree of dissection and age (Yanagida and Hasegawa, 1993).

Fifty-eight landslide areas were studied to measure the degrees of dissection with respect of formation date in this study. We noticed that there is a remarkable association between degree of dissection (D) and formation date (T) shown by the equation (Fig. 1).

With this, we estimate that landslide topographies lose around 3.5~16% in ten thousand years, 15~30% in one hundred thousand years, and completely disappear in one million years.

With this association, we can easily find the ages of landslides, which will be beneficial in checking the stability of landslides.

REFERENCES

Ueki, T., 2005, Tephrochronological age estimate of the Nakauchi Landslide in western Tokushima Prefecture, southwest Japan. Japan Landslide Society, v. 42, pp. 223–227.

Yanagida, M. and Hasegawa, S., 1993, Morphological dating and dissection process of landslide topography. Landslides, S. Novosad and P. Wagner (ed.), pp. 117–122.

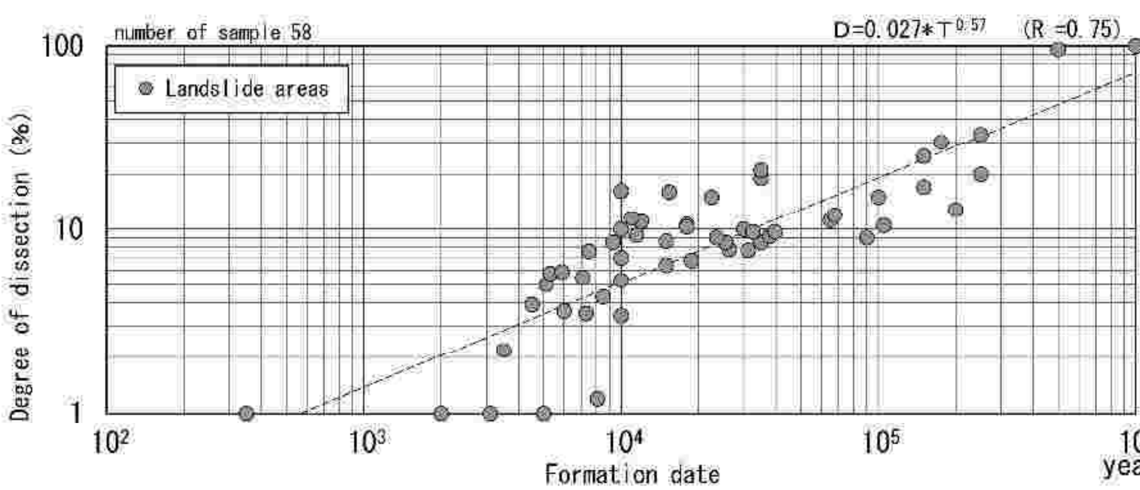


Fig. 1, Association between the formation date and degrees of dissection

Landslide mapping, characterization and mitigation in the Sub-Himalaya of Nepal

***Subodh Dhakal[1], Suman Pandey[2], Niraj Bal Tamang[2], Kumod Raj Lekhak[2], Shanta Bastola[2], Padam Budha[2], Bijaya Maharjan[2], and Gaurab Singh Thapa[2]**

[1] *Department of Geology, Tribhuvan University, Tri-Chandra Campus, Nepal*
[2] *Central Department of Environmental Science, Tribhuvan University, Nepal*
**Corresponding author: dhakalsubodh@gmail.com*

Landslides and surface erosion are the major environmental threats in the Sub-Himalaya of Nepal, also called Siwaliks (PCTMCDB and TU-CDES, 2016). Lithospheric plate tectonics, weak geological conditions, intense monsoon precipitation, river dynamics and human activities are some of the major processes that have been causing such geo-hazards in these youngest hills of Nepal (Dhakal, 2015). Only the scientific researches integrated with social dimension can provide the solution of such problems based on the cause and effect analysis. However, science based research with the objectives of identifying and minimizing the effect of landslides are lacking in this important geographical zone of Nepal. Realizing the lack of adequate and appropriate research, which is essential for the conservation of the Sub Himalayan zone itself and sustainable development in this area, Tribhuvan University, Central Department of Environmental Science (TU-CDES) conducted this research in collaboration with the President Chure Tarai Madesh Conservation Development Board (PCTMCDB/GoN). The ultimate goal of this research was to map the existing landslides, characterize them, rank the area in terms of the probability of the occurrence of landslide in future, conduct risk mapping and give mitigation options for high risk landslides. The study area belongs to the Sub Himalayan zone of twelve districts of Far Western and Mid Western Nepal namely Kanchanpur, Dadeldhura, Kailai, Doti, Bardiya, Surkhet, Banke, Dang, Salyan, Pyuthan, Argakhanchi and Kapilbastu. Landslides were delineated from Google Earth of different dates, verified them in the field, characterized in the field and recommended the mitigation options based on the geometry and geotechnical properties of the site. The urgency of mitigation was judged from the vulnerability and risk assessment as well as the geotechnical and geographical attributes of the landslides, which could better clue on the possibility of reactivation of landslides in future.

The study depicts that Kailali, Surkhet, Dang and Dadeldhura districts are highest ranked in terms of number and area of landslides and surface erosion. The landslide occurrence is dominant in Midldle Siwalik followed by Lower Siwalik. Rock slides, rock falls, debris slides, earth slides and complex landslides are found to be dominant in the study area. It is found that the interbedding of weak mudstone and strong sandstone lead to differential weathering, and the rock slides were triggered in Middle Siwalik. High degree of weathering, poor drainage and surface erosion are the reasons for different types of landslides in Lower Siwalik. Granular flow initiated by the washing away of cementing materials in the conglomerate beds of Upper Siwalik are found to be the major processes of landslides in this zone. Based on the field study and laboratory analysis, it is found that cost effective bioengineering techniques are most feasible to mitigate the landslides in this area. Surface drainage management, suitable plantation along with river bank protection and check dams are the components to be incorporated for effective mitigation. Many landslides were found to be naturally stabilized due course of time by the readjustment and re-vegetation in the slope.

REFERENCES

PCTMCDB and CDES-TU, 2016, Landslide Atlas of Chure Region 2016 with characterization and Mitigation Design, Part I. President Chure-Tarai Madhesh Conservation Development Board, Government of Nepal, Kathmandu and Central Department of Environmental Science, Tribhuvan University, Kirtipur

Dhakal, S., 2015, Evolution of Geomorphologic Hazards in Hindu Kush Himalaya, In: Shaw, R. and Nibanupudi, H.K (Eds.), Mountain Hazards and Disaster Risk Reduction, Springer Japan, DOI: 10.1007/978-4-431-55242-0_4.

Hydrological impacts on mechanism of mass wasting in Sub-Himalayan region with spatial reference to rock and soil condition

***Suman Panday[1], and Subodh Dhakal[2]**

[1]*Central Department of Environmental Science[1], Tribhuvan University, Kirtipur, Kathmandu, Nepal*
[2]*Department of Geology, Trichandra Campus, Tribhuvan University, Ghantaghar, Kathmandu, Nepal*
**Corresponding author: sumanpanday72@gmail.com*

Genetically formed by the very weak, fragile and youngest rocks of the Himalaya, and lying in the most dynamic area within the Himalaya, Sub-Himalayan region area is exposed to various types of slope instabilities and landslide hazard. Geologically, the Sub-Himalayan region is popularly known as Siwalik (Chure in Nepali language) belonging to age of the Middle Miocene to Upper Pleistocene (1 to 14 million years old), lies between the Lesser Himalaya in the North and Terai in the south and are lying within namely Main Frontal Thrust (MFT) in the south and the Main Boundary Thrust (MBT) in the north (Gansser, 1964).The rocks of the Siwalik are the boulder-cobble conglomerate, coarse-grained, "Pepper and Salt" sandstone, mudstone, shale and pebbly sandstone.

The study area includes the sub Himalayan region of the Makawanpur, Bara, Rautahat, Sindhuli, Sarlahi, Mahottari, Dhanusha, Udayapur, Siraha and Saptari districts and research based on detailed field investigation and landslide mapping besides any laboratory analysis of rock and soil. To analyze the precipitationcondition by using data of Department of Hydro-Metrology of 1989-2015 in the study area, isohytal map is prepared for all the working districts.

In the study area, more than 50 percentages of rivers are ephemeral, whichonly flows when there is rain and rest of the year there is just a dry river bed with absenceof water. Remaining rivers are seasonal and perennial in small number. It isunderstood that maximum amount of rainwater flows through surface and very little amount is infiltrated or recharge into the ground which is illustrated by the presence of dry landslides and ephemeral rivers. Rainfall triggers on the surface of very fragile and loose geology results surface erosion and landslides including debris and earth flow. Among all, the effect of water is observed in the form of bank scouring, riverside erosion and toe cutting of the slope and old landslides by river. The surface water also plays dominant role on head erosion and the initiation of landslides from the top of the slope

Toe cutting process is seen on slope containing soft thin layer in between massive rocks, dipping of rock is parallel to hill slope and hill slope is covered by thick weathered soil, which diverts the river meanders of river by deposition of debris materials in other bank.Head erosion process is developed by increasing the area of small gully erosional area by surface runoff of rainwater, penetrating of groundwater with high velocity in loose or soft soil and rock found maximum at head region of ephemeral rivers. Valley widening/ deepening/ rising river bed process is mixed process of both toe cutting and head erosional processes characterized by transportation of huge debris materials with high velocity after rain caused both bank erosion of both bank. Fluctuation in rain fall effects on deposition as well as down erosion of debris materials on river bed. Onless compacted massive sandstone and mudstone bed, downward erosion is occurred by the attrition process of running water. The Sub-Himalayan is frequently affected by initial failure in topographic hollows and valleys, developing scars and debris masses, which are main hydrological effects ground condition of rock and soil easily prone to erosion and water infiltration.

REFERENCES

Gansser, A, 1964. Geology of the Himalayas. London/New York/Sydney: Wiley Interscience, 289 p.

Landslide susceptibility mapping along central part of the Badi Gad Fault-an active fault of the Lesser Himalaya in Juhan-Shantipur area of Gulmi District, West-Central Nepal

***Sunil Bikram Thakuri, and Kabi Raj Paudyal**

Central Department of Geology, Tribhuvan University, Kirtipur, Kathmandu, Nepal
**Corresponding author: bikramthakuri2069@gmail.com*

The landslide susceptibility mapping along the central part of the Badi Gad Fault was carried out in the Juhan–Shantipur area of the Gulmi district in west-central Nepal. The aim of the study was to characterize the Badi Gad Fault, an active fault of the Himalaya and its present and future effects in the community. For that, a geological map was prepared covering about two topo-maps in the scale of 1:25000. The rocks of the region can be mapped into two lithological units as the Nourpul Formation and the Dhading Dolomite. The name of these units was derived from the most adopted geological units of the Lower Nawakot Group in central Nepal. The Nourpul Formation consists of mixed type of lithology of phyllite and metasandstone in different colors and composition. The Dhading Dolomite consists of medium to massive-bedded, highly-brecciated, and grey to white-colored siliceous stromatolitic dolomite with some pelitic partings and ortho-quartzites.

Landslide susceptibility mapping covers the area of about 133.8 km^2.A detail landslide inventory map was prepared covering with old and recent landslides. Causes of each landslides were documented in the field. In order to explain the landslides, various factors, i.e. slope, land use, geology, soil type, elevation, distance from rivers, annual precipitation and aspect and curvature were selected and susceptibility map was prepared using GIS software with weightage by the frequency ratio method.

The landslide susceptibility map shows that low, medium and high susceptibility area as 66.807 km^2 (49.2%), 48.15 km^2 (35.47%) and 20.8 km^2 (15.32%) respectively. The detected landslide area in the low, medium and high susceptibility classes are found 0.23 km^2 (11.14%), 0.63 km^2 (30.31%) and 1.22 km^2 (58.54%) respectively. Existence of large landslides and clustering of several landslides along a linear belt along with a number of shear zones represent the existence of the Badi Gad Fault.

Landslide susceptibility zonation using Analytical Hierarchy Process (AHP) in Dharamshala Region, Himachal Pradesh, India

[*]Swati Sharma[1], and A. K. Mahajan[2]

[1]*Department of Environment Science, Central University of Himachal Pradesh, H.P. (INDIA)-176206*
[2]*Department of Environment Science, Central University of Himachal Pradesh, H.P. (INDIA)*
[*]*Corresponding Author: swati.9238@gmail.com*

The research presents the use of analytical hierarchy process in landslide susceptibility mapping (LSM) for Dharamshala region, Himachal Pradesh, India. The unplanned construction over high hill slopes coupled with unsystematic sewage system around Dharamshala town in Kangra valley is marked by the presence of active landslides and land subsidence events. The factors studied for the LSM were lithology, soil type, slope angle, aspect, land-cover, distance to drainage, distance to fault and distance to road. The factor and their classes were assigned numerical ranking based on their weightage using comparison matrix method. The consistency ratio for the comparison matrices of various factors are satisfactory ranging below 0.1. The lithology has highest weightage 0.18 followed by slope angle and soil type with weightage of 0.15 each. LU/LC and drainage buffer have weightage value 0.13 each, whereas road buffer, aspect and fault buffer show low weightage values (0.10, 0.08 and 0.08 respectively). The landslide Susceptibility Index values were obtained by linear weighted sum/multivariate criteria analysis in which all the thematic layers were integrated. The resulting Index Map was classified in to four types of landslide susceptibility classes, i.e. very Low, low, medium and high susceptibility. The results show that 56.37% of the area is highly susceptible to landslides. The results obtained were validated and found to be in concordance with the landslide density in each susceptibility class. The validation was also performed by plotting a success rate curve between landslide susceptibility index and the landslide testing data in which 72.24% area under curve (AUC) value was achieved.

Effects of antecedent rainfall and snow melt on the volume of earthquake-induced landslides associated with inland fault activities in Japan

Taku Komatsubara

Geological Survey of Japan, AIST
E-mail: komatsubara-t@aist.go.jp

There are some mentions on relationship between the antecedent rainfall and the volume of earthquake-induced landslides. No one have still not systematically described on their relationships except for Dellow and Hancox (2006). The author tried to describeit on Japanese historical earthquakes.

The author listed up thirty historical earthquakes since mid-19th century Table 1, which were caused by inland active faults and their magnitudes bigger than M 6.8. Meteorological data are after historical documents before AD 1871 and after Japan meteorological agency (2016) since AD 1872. The volumes of landslidesare after the Japan landslide society (2012). The author pays special attention to snow cover, total rainfall during 7 days before the earthquakes and volume of debris mass in the biggest landslide among each event.

The relationship between debris volume and antecedent rainfall are shown as in the following figure. This figure suggests that a semi logarithmic relationship between two parameters can be seen, and snow cover tends to cause huge landslides.

REFERENCES

Dellow, G. and Hancox, G.T., 2006, The influence of rainfall on earthquake-induced landslide in New Zealand. in New Zealand Geotechnical Society 2006 Symposium 2006, Nelson, New Zealand. Institution of Professional Engineers of technical groups/Institution of Professional Engineers New Zealand.

Japan meteorological agency, 2016. Searching Page for past meteorological data. http://www.data.jma.go.jp/obd/stats/etrn/index.php?prec_no=40&block_no=47646 (cited on Nov. 26, 2016)

The Japan Landslide Society, 2012. Earthquake-induced Landslides. (in Japanese). The Japan Landslide Society, 302p.

Typology of landslides caused by 2016 Kumamoto Earthquake in Japan

***Tomoyuki Takami[1], and Takashi Inokuchi[2]**

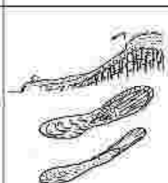
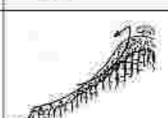
[1]*Tohoku Branch, Kokusai Kogyo Co., Ltd., Sendai Japan*
[2]*National Research Institute for Earth Science and Disaster Resilience, Tsukuba, Japan*
**Corresponding author: tomoyuki_takami@kk-grp.jp*

The 2016 Kumamoto Earthquake had caused many co-seismic landslides along the Futagawa fault that was estimate to cause this earthquake (Takami et al., 2017). In the western part of the caldera formed by Aso volcano, that is eastern end of this fault, various types of landslide related to topography and geological conditions were observed. These show the characteristics of the co-seismic landslide. Various forms of co-seismic landslides were classified into six types based on topography, geological setting, and movement modes (Table 1; Fig. 1).

Most characteristic type of co-seismic landslides (type 1) is on the gentle slope covered by mantle bedded volcanic ash fall and pumice layer with the gradient of about 30° or less. Landslides of this type had evolved from translational slides to earth-flows, run out about several hundred meters and damaged houses and people. Rock slides and topples, rock falls (type 3) occurred in crack-rich lava on steep slopes and cliffs eroded by the Shirakawa River. Relatively deep slides (type 2) had occurred in weathered and loosened bedrock composed of lava and volcanic breccia. In steep slope like caldera wall, shallow slides (type 4) had occurred in surface material which consists of volcanic ash and their weathered mantle. In the Aso caldera filled with soft lake deposit, lateral movement (type 6) of about three meters had occurred in the area about one square kilometer. This landslide formed elongate depression and damaged rice field and a bridge.

For assessing co-seismic slope hazard risks, it is important to know the relation between these landslide and geological condition such as topographic, geological setting, seismic ground motions and active faults.

Table 1: Typology of Co-seismic Landslides

type of landslide	schematic profile	type of movement	topography	geology
(1) fluidization of volcanic ash fall layer		·earth slide ·earth slump ·earth flow and their complex	gentle convex slope of less than 30 degrees.	volcanic ash fall layer incuding pumice and scoria with mantle bedding
(2) loosened weatherd rock failure		·rock slide ·debris slide	rounded slope without gully erosion. incline more than 30 degrees	wethered and loosened lava and pyroclastic rocks with joints and minor fault
(3) steep rock slope faiure		·rock slide ·rock toppling ·rock fall	riverside steep slope and cliff, incline more than 50 degrees	lava layer with joints, especially steep rock slopes with vertical cracks such as columnar joints
(4) surface collapse on steep slope		·earth slide ·earth fall	steep convex slope, incline 35 degrees or more	black soil and weathord volcanic ash (Kuroboku and Rohm), weathered zone of lava and pyroclastic rocks.
(5) collapse of embankment		·earth slump	high embankment on convex slope. valley fill embankment	sediments generated from cutting or tunneling
(6) lateral movement of soft sedimentary layer		·earth slide (lateral spread)	alluvial plane in caldera (incline less than 5 degrees)	lake deposits composed with soft clay and loose sand layer

REFERENCES

Takami, T., Inouchi, T., Kato, Y., and Nishiyama, K., 2017. Characteristics of slope disaster due to the 2016 Kumamoto Earthquake, and classification from topographic and geological condition, Report of the 2016 Kumamoto, Oita Earthquake Disaster Research Mission, pp. 85-95.

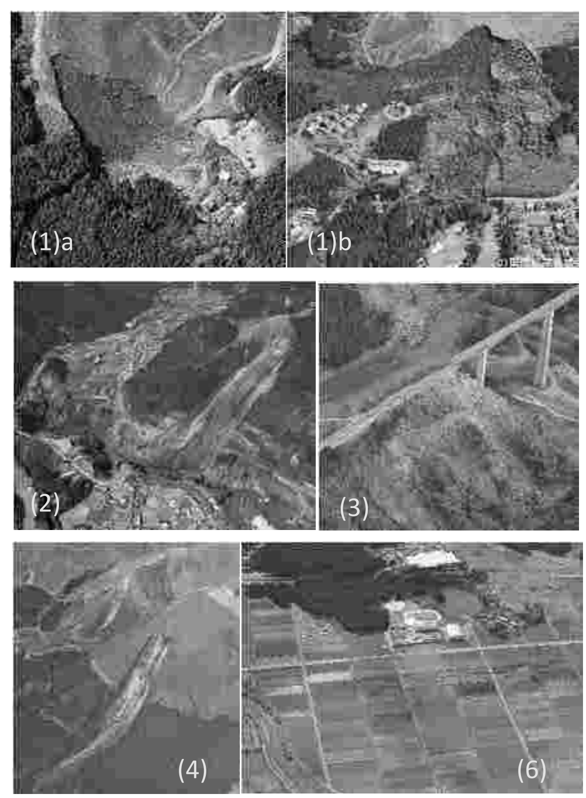


Fig. 1, Aerial photos of landslides
The numbers in photos correspond to the numbers in Table 1: (1) Takanodai district, (2) Aso Ohashi bridge, (3) Choyo Ohashi bridge, (4) Caldera wall in northwest of Aso volcano, and (6) Asodani lowland

Groundwater fluctuation simulation in Pagelaran Landslide, Cianjur, Indonesia

***Twin H. W. Kristyanto[1,3], Asriza[2], Reza Syahputra[3], and Tito L. Indra[3]**

[1]*Institute of Applied Geology, National Central University, 32045 Zhong-Li, Taiwan*
[2]*Geophysics Study Program, FMIPA, Universitas Indonesia, Depok, Indonesia*
[2]*Geology Study Program, FMIPA, Universitas Indonesia, Depok, Indonesia*
**Corresponding author: twin.hosea@sci.ui.ac.id*

Pagelaran is one of areas in the southern part of Cianjur, Indonesia. This area has high susceptibility of landslide (Anonymous, 2014). One of landslide in Pagelaran, which happened on December 2014, has destroyed 13 houses and damaged vital road along 200 meters. A year later, it started to conduct observation regarding the slope.

The research aimed to know the role of groundwater level fluctuation in the Pagelaran Landslide. The geometry of slope and its slip surface were determined using Electrical Resistivity Tomography (ERT) (McCann and Foster, 1990; Telford et al., 1990). The actual groundwater level was determined by measuring it from surrounding artesian wells. Parameters angle of friction, cohesion, and unit weight were obtained from laboratory tests toward undisturbed soil samples. These data were used for analysing the actual slope stability condition. Then the simulation of slope stability was conducted in accordance with fluctuations of groundwater level (Fellenius, 1939). The simulation was done by raising the groundwater level with range of 0.5 m.

The results showed that the actual slope stability was in critical condition with the value of safety factor 1.044. It also showed that slope stability waned as rising of groundwater level. The value of safety factor was reduced by an average of 0.034 in each 0.5 m up of groundwater level until it became failure (FS<1) when the groundwater level was 0.95 m above the actual position.

Therefore, it can be concluded that the position of groundwater level played a role toward the stability of slope in Pagelaran. To prevent the rising of groundwater level in rainy season, which can trigger landslide, it can be attached to pipes along the slope body to flow the groundwater through them.

REFERENCES

Anonymous, 2014, Landslide Vulnerability Map of Cianjur Regency, West Java (Indonesian Centre of Volcanology and Geological Hazard Mitigation).

Fellenius, W., 1939, Erdstatisch Berechnungen Revised Ed. W. Ernst und Sohn, Berlin.

McCann D. M. and Foster, A 1990. Reconnaissance geophysical methods in landslide investigations, Engineering Geology, v. 29, pp. 59–78.

Telford, W.M., L.P. Geldart, and R.E. Sheriff, 1990, Applied Geophysics 2nd Edition, Press Syndicate of University of Cambridge, New York.

Rock slope stability analysis along KM-34 – KM-45 in Tawaeli-Toboli area, Central Sulawesi, Indonesia

***Urwatul Wusqa[1], and Imam Achmad Sadisun[2]**

[1]Engineering Geology Laboratory, Faculty of Earth Science and Technology, Bandung Institute of Technology, West Java, Indonesia
[2]Geological Engineering Study Program, Faculty of Earth Science and Technology, Bandung Institute of Technology, West Java, Indonesia
**Corresponding author: urwahw@gmail.com*

Occurrences of landslide are most common and critical issue in Indonesia. The various types of slope failures have been affected most part of slopes and road section between Tawaeli to Toboli area (approx 40 km) within Donggala and Parigi-Moutong Districts, Central Sulawesi, Indonesia. These slope failures causes considerable loss of life and property along with many inconveniences such as disruption of traffic along highways. The unscientific excavations of rock slopes for road widening or construction purposes may weaken the stability of the slopes. The rocks exposed in the area are highly jointed schist and Granite of Palu Metamorphic Complex. The present study includes the kinematic analysis of the slope to assess the potential failure directions as the rocks are highly jointed in some parts of road cut sections. The slope mass rating (SMR) technique has been applied for slope stability analysis at 14 vulnerable locations. Kinematic analysis indicates mainly wedge type of failure along with few toppling and planar failures. These failure required immediate treatment to prevent the slide and long term stability of the slope.

Journal of Nepal Geological Society, 2017, Vol. 54 (Sp. Issue)

Landslide hazard assessment for pipeline of natural gas transport: experiences from TAP pipeline along Greek and Albanian territory

***Marinos V.[1], Stoumpos G.[2], Papathanassiou G.[1], and Papazachos K.[1]**

[1]Aristotle University of Thessaloniki, Department of Geology, 54124, Thessaloniki, Greece
[2]Engineering Geologist MSc, Menippou 33, 12135, Peristeri, Greece
**Corresponding author: marinosv@geo.auth.gr*

Landslides and unstable ground pose a significant threat to buried natural gas pipelines since they can generate permanent ground displacement (PGD) along or across the pipeline alignment. PGD is an important concern since a buried pipeline must deform both axially and in bending in order for the movement of the surrounding ground to be accommodated (Nyman et al., 2008).

Pipeline rupture is not uncommon in incidents caused by landslides. As such, landslide-related incidents often result in leaks that may have severe environmental impact as well as long periods of operational stoppage (Savigny et al., 2005). Regarding pipelines running through mountainous areas, statistics show that landslides are the most common cause of pipeline rupture and as such the most significant operational risk (Sweeney et al., 2005).

It is generally accepted that avoidance of landslide-prone areas is the most effective hazard reducing option both in terms of cost and time saving. Sweeney et al. (2005) point out that this is due to the fact that the investigation and the subsequent stabilisation of a significant number of landslide areas is not a practical undertaking mainly due to time and cost constraints. Accordingly, in mountain regions, the presence of landslides or the presence of landslide-prone areas is a quite important factor for the finalisation of the pipeline route.

It is important to be realistic about the precision and reliability of the assessed levels of hazard in the various identified sites. The results should provide a "high level" indication of how landslide hazard and risk is expected to vary through a mountain terrain and have to conclude identifying "hot spots" along the route where risk reduction measures should be prioritised. This information can be used to perform numerical analyses for slope stability assessment and the corresponding pipeline verification, in order to provide quantitative support to an expert classification of landslide risk. This assessment though, cannot be however a substitute for more detailed site evaluation that would be required to support the design and construction of mitigation measures at the critical slopes according to EN1997 and EN1998.

This work mainly focuses on the assessment of landslide hazard along or across a natural gas pipeline project and on the identification of these hazards, mostly in the field. The assessment must be based on extensive field work evaluation of all findings along the pipeline route, desk study of available data and ground investigation campaigns. Whether the "expected" landslide event reaches the Right of Way (RoW) and impacts the pipeline, is influenced by the nature and size of the expected landslide event, controlled by the site geology and geomorphology, the proximity of the existing landslide feature to the pipeline and the position of the pipeline relative to the landslide.

Experiences from TAP (Trans Adriatic Pipeline) pipeline along Greek and Albanian territory are presented as part of an implemented geohazard assessment along a challenging geological environment.

REFERENCES

Lee, E.M., Audibert, J.M.E., Hengesh, J.V. and Nyman, D.J., 2009, Landslide-related ruptures of the Camisea pipeline system, Peru. Quarterly Journal of Engineering Geology and Hydrogeology, v. 42, pp. 251–259.

Nyman, D., Lee, E M and Audibert, J M., 2008, Mitigating geohazards for international pipeline projects: challenges and lessons learned. IPC2008-64405. Proceedings of IPC 2008: 7th International Pipeline Conference Calgary, Canada.

Savigny, K.W., Porter, M. and Leir, M., 2005.Geohazard risk management for the onshore pipeline industry. Business Briefing: Exploration and Production: The Oil and Gas Review, v. 2, pp. 1–3.

Sweeney M, Gasca, A H, Garcia-Lopez M and Palmer A C 2005, Pipelines and landslides in rugged terrain: a database, historic risks and pipeline vulnerability. In M. Sweeney (ed.) Terrain and geohazard challenges facing onshore oil and gas pipelines, pp. 641–660.

Understanding the potential severity of large landslide events through computational modelling

***Vincent Lemiale[1], Ha Bui[2], Shaohan Zhao[2], Laura Karantgis[3], Philip Broadbridge[3], and Deepak Adhikary[4]**

[1]CSIRO Data61, Clayton, VIC, Australia
[2]MCG Lab, Department of Civil Engineering, Monash University, Clayton, VIC, Australia
[3]La Trobe University, VIC, Australia
[4]CSIRO Energy, Pullenvale, QLD, Australia
**Corresponding author: Vincent.Lemiale@csiro.au*

Landslides continue to claim thousands of lives and cost billions of dollars annually. Although early warning systems have been developed, these are still in their infancy and cannot reliably predict the potential severity of a landslide in regions at risk. One reason for this is that each landslide is intrinsically unique and depends on many factors includingslope characteristics, soil type, vegetation, soil depth and local conditions such as rainfall data.

Conventional numerical methods such as the finite element method have been used for slope stability analysis since the 70s (Zienkiewicz et al., 1975). Unfortunately their application to post-failure mechanical analysis is limited due to the necessity of dealing with very large deformations as well as the initiation and propagation of macroscopic discontinuities. Alternative discretization schemes that do not involve a mesh have been proposed to alleviate these issues. Two have received particular attention in recent years, namely the Material Point Method (MPM), (Llarno-Serna et al., 2016) and Smoothed Particle Hydrodynamics (SPH) (Bui et al., 2008).

In this paper we focus on the application of SPH to the modelling of rainfall induced landslides, as it is truly a meshless method, as opposed to MPM which still requires a background grid to carry out the numerical integration. This characteristic of SPH makes it quite flexible in dealing with complex geometries and boundary conditions (Mead et al. 2017) and allows multi-physics formulation to be implemented relatively straightforwardly. SPH is a numerical method for solving partial differential equations that relies on the interpolation of functions at any location in terms of their values calculated at a set of surrounding material points or particles. The interpolation step involves a known function (the kernel) that can therefore easily be differentiated so that gradients terms can be readily derived. This allows partial differential equations to be converted into ordinary differential equations that can then be solved using standard numerical integration schemes.

We will focus on rainfall induced landslides since they are one of the most common and devastating events occurring in nature. The model consists of three steps. Firstly, the change in water content is calculated based on the amount of rainfall received and the local characteristics of the slope. This might involve complex internal structures such as internal faults and joints which can affect the rainfall infiltration. This first step is then sequentially coupled with a slope stability analysis which considers both the porewater pressures and a possible change in soil mechanical properties with the increase in water content. Finally, once the slope has failed, a post-failure analysis is carried out which estimates the damage caused by the failing volume through its interaction with its surroundings. It is important to note that in our approach these three steps are all performed using just one numerical method, SPH, thus streamlining the analysis considerably.

We will first demonstrate the suitability of SPH model on several examples of slope failure and will compare our results with existing experimental and numerical results, as well as field observations; SPH analysis of an OB dump failure in a coal mine in India will also be presented. It will be shown that the method can accurately capture all phases of a landslide, including strain localization leading to catastrophic shear failure. The method therefore represents a promising avenue for supplementing landslides warning systems with detailed local analyses in areas at risk. This in turn will help improve the accuracy of the forecasting and can also be used for planning and mitigation purposes.

REFERENCES

Bui, H.H., Fukagawa, R., Sako, K., Ohno, S., 2008, Lagrangian mesh free particles method (SPH) for large deformation and failure flows of geomaterial using elastic-plastic soil constitutive model. Int J Numer Anal Met, v. 32, pp 1537–1570.

Llano-Serna, M.A., Farias, M.M., and Pedroso, D.M., 2016, An assessment of the material point method for modelling large scale run-out processes in landslides. Landslides, v. 13, pp. 1057–1066. doi: 10.1007/s10346-015-0664-4

Mead, S.R., Magill, C., Lemiale, V, Thouret, J. C., and Prakash, M., 2017, Examining the impact of lahars on buildings using numerical modelling. Natural Hazards and Earth System Sciences, v. 17, pp. 703–719.

Zienkiewicz, O.C., Humpheson, C, Lewis R.W., 1975, Associated and Non-Associated Visco-Plasticity and Plasticity in Soil Mechanics. Geotechnique, v. 25, pp. 671–689.

Kinematics of some typical rock slides in Himalaya

V. K. Sharma

C-1/492 A, 'Divya villa', Sector-G, Jankipuram, Lucknow-226021, India
E-mail: vksharma.geo@gmail.com

Catastrophic rock slides in Himalaya generally occur in high relief conditions and their impact is extremely hazardous while rapidity of dislodged blocks render large part vulnerable in downslope areas. Depending upon the volume and nature of displaced material, cascading run out, the consequential effects are variable. These extremely rapid (> 25 ms^{-1}), large (> $1x10^6$ m^3) mass movements, are potentially very destructive. In general, the rock avalanches are high magnitude, low frequency events, triggered either by hydro-metereological or seismic conditions on higher slopes. After detachment, the key factors that dominate the flight of the rock-mass are geometry and material of the slope. These factors outline the motions of the rockfall which may be classified into four types-free fall, sliding, rolling and bouncing (Ritchie, 1963). In Himalaya such large rock slides have long been recognized especially in higher domains of its easternmost extremity encompassing Arunanchal and Sikkim Himalaya and Northwest sector of Kumaon, Garhwal, Himanchal and Ladakh Himalaya. These domains have witnessed societal and morphological impacts on account of recurring rock slides.

During last century rockslides of frightening proportions have been well recorded from the Himalayan belt. The slope instability around Nainital in Kumaun Himalaya where a disastrous landslide (1880, 1896) along a planar discontinuity inflicted colossal loss of life and property has been well documented. This was the pioneering investigations in India that dates back 1896. The catastrophic rock slide (1893) in Birehiganga valley in Garhwal Himalaya leading to creation of a huge reservoir had an impact on the geo-environment of the fragile mountain system. The National highway in Sikkim is the vulnerable corridor where numerous rock fall zones are controlled by intense shearing in the Lesser Himalayan lithology leading to numerous rock slides. The Himalayan syntaxial band in the eastern part of the Arunanchal Himalaya is a structurally deformed zone with high potential of rock fall hazards.

In last decade or so there has been a phenomenal rise in rock fall events which have impacted the life of the people in the entire mountain belt. The lake formation caused due to the blockage of the river by a sudden rockslide (2004) in Parechu River, Varnavrat slide (2003) posed threat to habitat areas. The disastrous rockslide at Malpa (1998) in the Higher Himalaya close to Indo-Nepal border buried over 220 people in a flash with complete vanishing of the village settlements and camping pilgrims. The extreme rapidity of the mass movement was a unique example of rock fall–cum-rock avalanche with hooting, bouncing and rolling of rock blocks of quartzite and rock dust engulfing 1–1.5 km radial area. The kinematics of all the discrete rock falls has been favoured by several factors including the high relief, geological discontinuities, glacial environment, ongoing seismic activity, and hydro-metereological conditions related to climatic change scenario. The recent rockslide in Sunkoshi River catchment of Nepal Himalaya, the Jure rock slide occurred on the 2nd August 2014 and killed 155 people (Jaboyedoff et al., 2015).

The record of cases of typical rock fall hazards in Himalaya bring out the predisposing kinematics of the phenomenon such as zone of maximum uplift rate within the crustal-scale ramp of the Himalaya (6-8 mm/yr; Bilham et al., 1997); proximity to the Himalayan thrusts *viz.* Main Boundary Thrust (MBT) and Main Central Thrust (MCT), shear zones and tectonic deformations ; local high relief; slope/discontinuity interplay and rockmass characterization. Structural data shows that thrusts environment has manifested in crushing and shearing of rocks, which play an important role in landslide proneness along with the rainfall intensity (Prakash et al., 2015).

The role of overall evolution of the hill slopes, potential hazard zoning, assessment of run out zone and development of early warning system by high resolution monitoring of slope instability for risk based approach has been emphasised for management of rock slides in high relief sectors.

REFERENCES

Bilham R.K., Larson K., Freymuller J., Project IDHYLIM members, 1997, GPS measurements of present day convergence across the Nepal Himalaya. Nature, v. 386, pp. 61–64.

Jaboyedoff, M., Leibundgut, G., Penna, I., Dahal, R. K., Sevkota, S., and Sudmeier, K., 2015, Characterization of the Jure (Sindhupalchok, Nepal) Landslide by TLS and field investigations. *EGU2015-11858-1.* Geophysical Research Abstracts, v. 17.

Prakash, C., Agarwal, K.K., and Sharma, V.K., 2015, Structural control of landsides in Eastern Kumaun Himalaya: case study from Sukhidang-Ladhiya Section. Jour. Geol. Soc. India, v. 86, no. 5.

Ritchie, A, 1963. Evaluation of rock fall and its control, Highway research record, v. 17, pp. 13–28.

Experimental research on the characteristic of seepage coupled with creep of landslide soil around reservoirs

Yu Wenpeng[1], *Wang Shimei[1], Hu Qiufen[1], Teng Shuai[1], and Lu Peng[1]

College of Civil Engineering and Architecture, China Three Gorges University, Yichang , China
**Corresponding author: 284480957@qq.com*

The groundwater seepage field changes due to the change of reservoir water level, and the seepage force of landslide soil is changed, which will influence the creep of landslide soil; on the contrary, creep can affect the permeability of landslide soil by altering its porosity which shows clear coupling induction of seepage and creep. For cohesive soil landslides, this kind of coupling induction is quite significant, so it meets the real mechanics development progress better only to take the coupling induction of seepage and creep into consideration. In this paper, we took the soil, taken from typical landslide in Three Gorges Reservoir Region, as research objects. And based on the self-developed seepage and creep coupling triaxial apparatus, we carried out triaxial creep tests under the conditions of different hydraulic head, and discovered the pattern of coupling of seepage and creep. The principal results are as follows:

1. By seepage tests under different consolidation stress, we obtained porosity and permeability of soil sample, and found out their relation model: $K=1.1144\times 10^{-8}\times e^{41.09073n}$. Their relation indicates that soil deformation has an influence on permeability. Permeability increases with porosity increasing.

2. By triaxial creep tests under constant net confining pressure and variational hydraulic head seepage, we obtained creep curves, and established creep model based on Fixed Burges Model. The results show that seepage has a significant influence on creep. With seepage developing, the deformation increases sharply for a short time, then grows slowly, and at last tends to a steady value and the creep deformation gets greater under higher seepage pressure.

3. Based on the creep formula we established, seepage governing equation, and k-n dynamic equation, we elicited a mathematic model of coupling between seepage and creep, which are as follows:

Therefore, the creep deformation under seepage can be solved, if we put porosity n and permeability k from seepage tests, and creep parameter from creep tests into the mathematic model we elicited.

Experiment of sudden initiation triggered by shearing vibration for locked segment of Wangjiayan Landslide

Hu Kai, and *Zhao Xiaoyan

Faulty of Earth Science and Environmental Engineering, Southwest Jiaotong University, Sichuan, Chengdu, China
**Corresponding author: xyzhao2@swjtu.cn*

The study of sudden initiation mechanism has always been a hotspot and difficulty in the research of high-speed landslide. Started with the vibration triggered by the shearing rupture of the locked segment, this paper will study the sudden initiation mode of the Wangjiayan Landslide and the starting acceleration through experiments of vibration triggered by the shearing rupture of rock. By defining the percentage of locked segment area from the total area of the latent sliding surface as locked segment area ratio, shearing rupture vibration experiments are carried out to the slate rock of different locked segment area ratio to analyse the connections between vibration acceleration and the area ratio of locked segment. Based on that, the influence of vibration triggered by the shearing rupture of the locked segment on the landslide initiation was studied and the mechanism for sudden initiation of the Wangjiayan Landslide was proposed. The results of test show that the vibration acceleration of shearing rupture increases with the increase of the area ratio of the locked segment and that the initiation of the Wangjiayan Landslide is an up-inclined cast, not the sliding along the latent sliding surface. At last, the starting acceleration and casting direction of the Wangjiayan Landslide is proposed.

Spatio-temporal evolution of geohazards after the 2008 Wenchuan earthquake

***Xuanmei Fan[1], Lanxin Dai[1], Qing Yang[1], Runqiu Huang[1], and Tristram Hales[2]**

[1]State Key Laboratory of Geohazard Prevention and Geoenvironment Protection, Chengdu University of Technology, 610059, Chengdu, Sichuan, China
[2]Cardiff University, Cardiff, UK
**Corresponding author: 18202308@qq.com*

The 2008 Wenchuan earthquake (Mw 7.9) in the Sichuan Province (China) triggered a huge number of landslides, with a total area of 811 km^2 and an estimated volume ~5-15 km^3 (Huang and Li, 2009; Yin et al., 2009; Parker et al., 2011; Huang and Fan, 2013). The enormous amount of coseismic landslides deposits are prone to reactivation during heavy rainfalls and largely promote the occurrence of post-earthquake debris flows.

After the earthquake, many research works were carried out to understand this devastating event and the potential effects of the post-earthquake landslide reactivations and debris flows. They are focused on: (i) investigation of case studies of different events, and mapping and analysis of co-seismic and post-seismic landslides and debris flows; (ii) analysis of the rain conditions for post-earthquake debris flow occurrence; (iii) evolution of the post-earthquake landslides and debris flow and their impact over an extended period and (iv) the long-term earthquake effect on the evolution of sediment transport.

To understand how long the earthquake impact will last and how did the geohazards evolve after the earthquake both in space and in time, we collected multi-temporal RS images from 2008, 2011, 2013 and 2015. By visual interpretation of these images, we created a new extensive and detailed multi-temporal inventory of the co-seismic and post-earthquake reactivations and new landslides. We also quantified the possible uncertainties by comparing the mapping results of different interpreters for an identical catchment. The results show that the reactivation rate decays quickly after the earthquake, especially after 2013, which almost returned to the pre-earthquake level. The box-plot shows that the size change of reactivation landslides over time, indicating that large landslides are prone to be active for longer period, probably due to the large amount material they produced (Fig. 1).

REFERENCES

Huang, R. and Fan, X., 2013, The landslide story. Nat Geosci., v. 6, pp. 325–326. doi: 10.1038/ngeo1806

Huang, R.Q. and Li W.L., 2009, Analysis of the geo-hazards triggered by the 12 May 2008 Wenchuan Earthquake, China. Bull Eng Geol Environ, v. 68, pp. 363–371. doi: 10.1007/s10064-009-0207-0

Parker, R.N., Densmore, A.L., and Rosser, N.J., et al., 2011, Mass wasting triggered by the 2008 Wenchuan earthquake is greater than orogenic growth. Nat Geosci, v. 4, pp. 449–452. doi: 10.1038/ngeo1154

Yin, Y., Wang, F., and Sun, P., 2009, Landslide hazards triggered by the 2008 Wenchuan earthquake, Sichuan, China. Landslides, v. 6, pp. 139–151. doi: 10.1007/s10346-009-0148-5

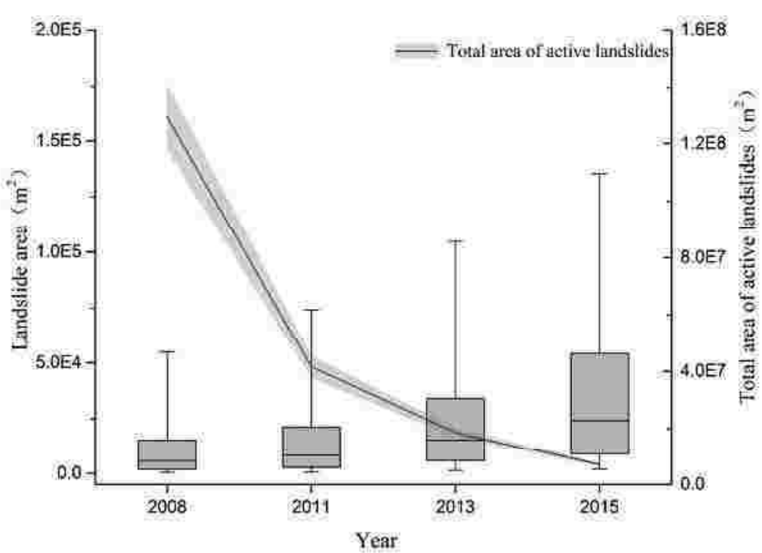


Fig. 1, Changing area of reactivation landslides over time after the Wenchuan earthquake

Research on the characteristics and instability mechanism of K3 altered basic rock slope in Lushi Highway

Xiaoyan Zhao, and *Xun Li

Faculty of Geosciences and Environmental Engineering, Southwest Jiaotong University, China
Corresponding author: 1134229895@qq.com

For the serious alteration of chip rock slope, the characteristics and process of rock alteration were analysed. The shear test was aimed to explore the influence on the shear strength parameters of rock discontinuity structural planes which have occurred pyrogenic alteration (weathering). Research results show that the main mineral alteration type of gabbro slope are chloritization, clayization, petrochemical, sericitization and epidotization, altered minerals mainly distribute in the rock discontinuity structural plane. The results of shear test show that the rock alteration (weathering) had a great influence on the shear strength parameters of the rock joint. According to the test results, using geotechnical calculation software to calculate the stability of landslide, the latter corresponds to the each test group. Analysis results prove that alteration (weathering) is the main factor of the slope destruction.

A comprehensive monitoring information system for landslide based on three-dimensional visualization and network

Xie Mowen, *Jia Yanchang, and Du Yan

School of Civil and Resources Engineering, University of Science & Technology Beijing, Beijing, 100083, China.
**Corresponding author: 384975907@qq.com*

With the rapid development of engineering construction, especially the various hydropower projects under the complex geological conditions, the safety monitoring for the high risk slope has become an important part of the project construction. The safety monitoring for Landslide today focused on the collection of data, which pay attention on the accuracy of the data itself, and the analysis of monitoring data was main single-point analysis. However, landslide, as such a complex geological body, especially for large-scale landslide, it is more efficient to overall analyse combined with the geological topography. Meanwhile, it is more meaningful to find a well-established method deepen the analysis and expression.

This article established a comprehensive monitoring information system combined with GIS technology, 3D visualization and network technology, which was certain significant for data acquisition, data display, data visualization, data expression, deepen analysis, forecast and early warning.

Slope deformation problem by earthquakes: a case study in the 2016 Kumamoto Earthquake site

***Yasuhito Sasaki, Ken-ichi Asai, and Yoshinori Yajima**

Public Works Research Institute, Tsukuba, Ibaraki, Japan
**Corresponding author: ya-sasa@pwri.go.jp*

Many slope movements have occurred by the 2016 Kumamoto Earthquake in Japan. The district is mainly composed of Quaternary lava, welded tuff, volcanic ashes and eolian deposits. As these strata are very soft and easily deformed, not only landslides but also many ‘slope deformations’ were observed.

The amount of displacement by the deformation varies from several millimeters to 5 meters or more. Slope deformation has induced many problems on infrastructures such as roads, railways and waterways. Especially for bridges, displacement of foundations should generally be limited within very small so that bridge body could suffer from devastating damages. Then the Japanese Ministry of Land, Infrastructure and Transport and Tourism (2016) has informed, after the earthquake, a new government notification on the geological investigation and resilient design of bridges against slope deformation by earthquakes. But there is no suitable method for estimating instability and ‘deformability’ of slopes at present. Therefore we tried to develop a simple method for estimating slope deformability before constructing infrastructures.

Topographically, due to the Kumamoto case, slope angle and slope shape are important. For example, highly deformed slopes were divided into four types, namely, type *O*: overhang slope, type *S*: shoulder of cliff (<50 degree), type *D*: divergent and convex slope (<40 degree), and type *N*: other normal slopes. Type *O* has appeared mainly in the area of columnar jointed lava and welded tuff. Type *S* has appeared in all Quaternary volcanics, and divided into two sub-types by shoulder geology, soil deposit type (*Ss*) and jointed rock type (*Sjr*).Type *D* and type *N* has appeared in volcanic ashes and auto-breccia. Risk rank of these types are estimated at $O \fallingdotseq Ss > Sjr > D > N$.

Geologically and mechanically, slope deformations were divided into seven types, (1) shallow soil creep and ductile deformation of volcanic ashes and auto-breccia, (2) shallow sliding/gliding with many open cracks of volcanic ashes and auto-breccia, 3: toppling of columnar jointed lava, (4) in-situ rolling of columnar and block jointed lava, (5) deep-seated sliding/gliding of volcanic ashes and auto-breccia, (6) active fault or tectonic deformation (all strata), and (7) mixture of slope deformation and tectonic deformation (soft strata).

Thus, deformability was complicatedly affected by topographical and geological/engineering geological factors. Then, a draft method of slope deformability classification in strong earthquake is proposed as Table 1 in which topographical and engineering geological elements are empirically combined.

Table 1: Slope deformability classification in strong earthquakes

Topography		Rock mass class / rock or soil condition				
Slope angle (degree)	Slope shape	A-B / Intact, sound rock	CH-CM / Normal jointed rock	CM-CL / Weathered, blocked, or columnar jointed rock	CL-D / Decomposed, or highly fractured rock, gravel	E / Soil (sand, silt, clay, etc.)
Overhang	凸	△	○	◎	◎	◎
	□、凹	△	△	○	◎	◎
50+	凸	△	△	○	◎	◎
	□、凹	△	△	△	○	◎
40-50	凸	—	△	△	○	◎
	□、凹	—	—	△	△	○
30-40	凸	—	—	—	△	○
	□、凹	—	—	—	—	△
5-30	凸	—	—	—	—	△
	□、凹	—	—	—	—	△

Legend of slope shape
凸 : divergent, convex, or shoulder of cliff
□ : straight, complex
凹 : convergent, concave

Legend of deformability
◎ : Highly deformable (50cm or more, meters)
○ : Deformable (10cm or more, a few tens of centimeters)
△ : Due to the rock/soil property or geological structure
— : Rare, or only small deformation (mm, cm)

Also, Asai et al. (2012) proposed instable geological structures by analyzing past earthquake cases as in Fig. 1. These types are also ‘deformable’ slopes. The accuracy of estimation will improve by the combination of both aspects.

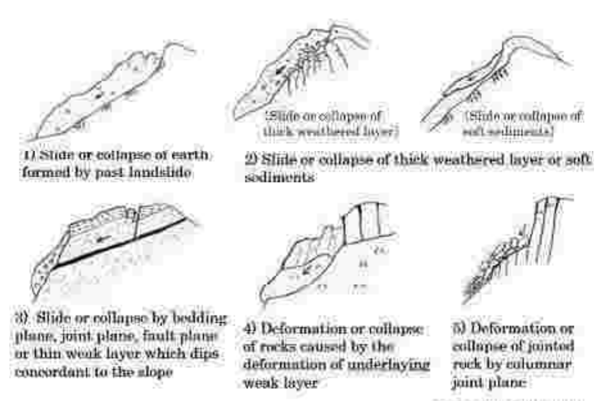


Fig. 1, Instable slopes in earthquakes (Asai et al., 2012)

REFERENCES

Asai, K., Agui, K., and Sasaki, Y., 2012. Slope deformation patterns by earthquake which influence the safety of structure foundations, Proceedings of 2012 Kanto Branch Conference of Japanese Geotechnical Society, CD-ROM (in Japanese).

Comparative study between debris flow of wide-gentle and narrow-steep channel based on hazard mechanism and prevention measures

Mei Han

Southwest Jiaotong University, Faculty of Mathematics, Chengdu, China
E-mail: hanmei@home.swjtu.edu.cn

Along Duwen freeway in "5.12" Wenchuan meizoseismal area 2008, there are two main types of debris flow channels, that is, wide-gentle channel and narrow-steep channel. The wide-gentle channel has the feature of gentle longitudinal slope, large mean width and catchment area. Whereas the narrow-steep one generally shows opposite features with narrow longitudinal slope, small mean width and catchment area. Under the heavy rainfall, these channels are subject to large-scale debris flows due to huge amount of earthquake-induced collapsing and sliding materials. In this thesis, we take Taoguan and Mozi gully for example respectively. With field investigation on the formation conditions and development characteristics of these two types of debris flows, we analyzed the resulting impaction, burying and blockage to the Duwen freeway and the Minjiang River. The formation mechanism behind the hazard of debris flows occurred in the above-mentioned two types of channels was intensively studied. Finally, prevention measures of the debris flow and effectiveness analysis of the treatment were proposed based on the features of the two channels.

Infinite slope stability analysis based on time distribution of rainfall in Ulleung-do, Korea

Seong-Woo Moon, and *Yong-Seok Seo

Department of Earth and Environmental Sciences, Chungbuk National University, Cheongju, Korea
**Corresponding author: ysseo@cbu.ac.kr*

In infinite slope analysis, the time distribution of rainfall is one of the most important factors along with geology, groundwater, topographic and soil characteristics. In this study, infinite slope stability analysis considering the time distribution characteristics of the daily maximum rainfall is conducted for use in development of real-time landslide early warning system. The study area, Ulleung-do, is a volcanic island 120 km east of the Korean Peninsula. The geology of Ulleung-do consists primarily of volcanic rocks, such as trachytic and pyroclastic rocks. The island has a humid subtropical climate with mean annual rainfall of 1,300 mm. In the past, several types of landslides have occurred on this island.

The analysis area is around 800 m × 680 m of the eastern part of Ulleung-do. The analysis program uses an infinite-slope model combined with temporal groundwater change model to calculate the safety factor on individual unit cells which is 5 m × 5 m.

Geotechnical parameters, such as soil unit, unit weight, friction angle, cohesion, porosity, and permeability, were determined by laboratory tests and the representative values have been chosen to carry out the analysis on the whole study area.

Within the last 40 years, the maximum daily rainfall record of Ulleung-do was 257.8 mm measured in 1981. Based on this record, the four types of time distribution curves of daily maximum rainfall were made using Huff's model. Finally, the effect of rainfall characteristics on the stability of infinite slopes was analysed by comparing the four types of calculation results showing different distribution of safety factors.

Implications for development along the Bhotekoshi River corridor, Nepal-China border area, from mass-wasting induced by the 2015 Gorkha Earthquake

***Ren-mao Yuan[1], Guo Wu[1], Xinfu Zeng[2], Dickson Cunningham[3], Qing Zhou[1], and Xiao-ping Yang[1]**

[1] *Institute of Geology, China Earthquake Administration, Beijing, 100029, People's Republic of China*
[2] *Earthquake Administration of Jiangxi Province, Nanchang, 330039, People's Republic of China*
[3] *Department of Environmental Earth Science, Eastern Connecticut State University, CT 06226, USA*
**Corresponding author: yuanrenmao@ies.ac.cn*

The 2015 Gorkha earthquake (Mw 7.8) and its aftershocks caused nearly 9000 deaths and more than 23,000 injuries and triggered thousands of landslides and other mass-wasting effects in the steep, rugged topography of Nepal. In this study, new slope failures and tension cracks induced by the 2015 Nepal earthquake are documented in steep terrain west of the Tatopani Border Station, which lies along the deeply incised Bhote Koshi River valley, a critical trans-Himalayan transport route between south Asia and Tibet/China. The affected area west of the Tatopani station is the site of a large reactivated paleo-landslide that has experienced repeated failures. The Tatopani station is downslope from the amphitheater-like landslide scar and is constructed on distal landslide debris in a position vulnerable to future landslide and fluvial erosion hazards. We carried out detailed field investigations to document different types of geohazards around the station and present an evolutionary model for past and present landslide development (Fig. 1). In addition, a simple numerical model was constructed to evaluate the stability of the large paleo-landslide body under different earthquake conditions. Simulated results suggest that the paleo-landslide body is stable without seismic loading. However, the large paleo-landslide will be remobilized again by large slope failures if the PGA of future earthquake exceeds 0.35 g. We suggest that the results presented in this paper should be taken into consideration during earthquake-resistant design of the border station and other infrastructural development along the Bhotekoshi Valley.

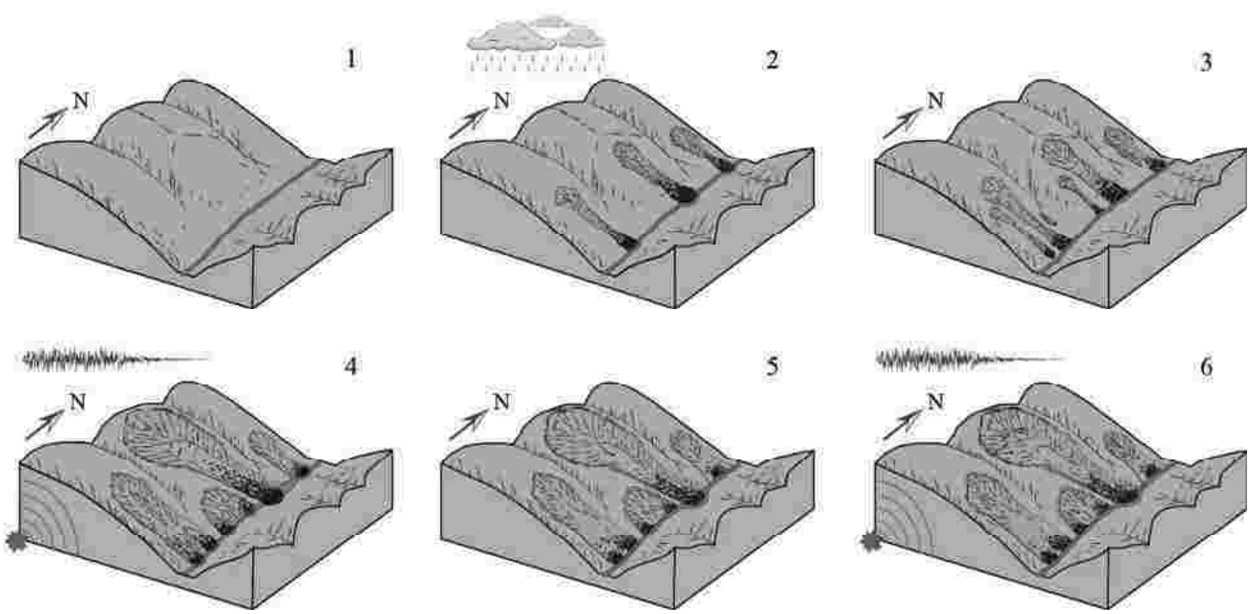


Fig. 1, Evolutionary model of the landslide area

Journal of Nepal Geological Society, 2017, Vol. 54 (Sp. Issue)

Dating a large scale debris flow event using terrestrial cosmogenic nuclide: an attempt in Marshyangdi River, central Nepal

***Yuki Matsushi[1], Hiroshi Yagi[2], and Hiroyuki Matsuzaki[3]**

[1]*Disaster Prevention Research Institute, Kyoto University, Japan*
[2]*Department of Education, Art and Science, Yamagata University, Japan*
[3]*Micro Analysis Laboratory, Tandem Accelerator, The University of Tokyo, Japan*
**Corresponding author: matsushi@slope.dpri.kyoto-u.ac.jp*

This study focuses on distribution of sedimentation terraces and their formation ages along the Marshyangdi River, south-eastern range of the Annapurna massif, central Nepal. These terraces exhibit characteristic morphology with hummocky mounds, indicating their origin that may be relevant to large scale sedimentation events by deep-seated bedrock landslide and subsequent barrier lake breach, and also by glacial lake outburst flooding (GLOF). Boulders settled on the terraces were sampled at three sites (28.09ºN, 84.45ºE) with varying height (20–50 m) from the present river bed. Rock types of those boulders are gneiss, which distributes upper reach of the basin. The samples were processed by physicochemical procedures and analyzed by accelerator mass spectrometry for measurement of cosmogenic 10Be in quartz for exposure dating of the boulders to determine the timing of the debris supply event. Exposure ages of the boulders range from 3.6 to 4.1 ka that coincide within statistical uncertainties, indicating that a single event under Holocene climate formed the terraces. A more comprehensive dataset is required for revealing the triggering factors and recurrence intervals of such large-scale debris supply events in the southern Himalaya range.

Mechanism of landsides along road in the Jiuzhaigou scenic spot, Sichuan, China

***Yun-sheng Wang, Bo Zhao, Jia Li, Tong Shen, and Qian-qian Feng**

State key Laboratory of Geohazard Prevention and Geoenvironment Protection, Chengdu University of Technology, China 610059
**Corresponding author: 287820171@qq.com*

The August 8, 2017 Jiuzhaigou, China Earthquake (Ms 7.0) according to Chinese Earthquake Administration-CEA directly triggered many landslides, which caused about 25 deaths, many landslides along roads were triggered by this seismic event. Combining with field investigations and aerial images, this paper introduces the mechanism of landslide along road.

It has been found that the Jiuzhaigou earthquake triggered about 812 landslides along roads, and they can be divided into: human induced slope failure and natural slope failure. Human slope failure is mainly induced by inappropriate engineering practices; such as slope excavation and unsuitable fill due to road construction. This type of landslides are mainly small scale landslides, and whose elevation is between -5 and 100 m above the road, and whose scales are mainly concentrated from a few cubic meters to thousands cubic meters, little can reach hundreds of thousands of cubic meters. Natural slope failure is mainly induced by old potential unstable rock mass. It can trigger larger landslides than human induced landslide. Natural slope failure occurs at the upper or top part of mountains, whose elevation is between 50 and 400 m above the road ,and whose scale is mainly concentrated from a few cubic meters to thousands cubic meters, and some can even reach hundreds of thousands of cubic meters.

Case study on rock slide susceptibility due to tunnel excavation

Yuzo Ota

Koken Engineering Co., LTD., Sapporo, Japan
E-mail: y.ota@koken-e.co.jp

It is empirically known, in Japan, that tunnel excavation should be at least 20 m away from the slip surface of any landslide. This paper presents a case study examining the possibility of a rock slide induced by tunnel excavation. In the investigated slope, a feature suggesting a potential landslide was found along the designed tunnel route. Three borehole drillings and loggings were carried out to assess its probability.

The study area is in a mountainous area of Miyagi prefecture located along the Pacific Ocean in Tohoku region, and it is composed of alternating layers of Paleozoic-Mesozoic shale and sandstone, both of which have been folded considerably. Each bed is generally tilted at an angle between 30 degrees and 40 degrees to the south, even though the area has been under the influence of anticline. The ground water level is low and only observed below the elevation of the tunnel because of many discontinuities due to bedding planes and folding joints.

The topographical research results are as follows; the landslide feature, which is similar to the main scarp of a rock slide, was found before the construction stage in the southward slope outside of the designed tunnel route (Fig. 1a). The slope including the scarp-like topography (small graben) dips approximately 40 degrees south-southwestward, and the graben strikes NNW-SSE. Therefore either a southward or a southwestward planar failure had to be considered (Fig. 1b; A-A' and B-B'). If the southwestward rock slide took place due to the excavation, it would cause damage to the highway, while the southward failure was deemed unlikely to have any impact.

In order to examine the potential failures, the author performed three borehole drillings and loggings. Two of them (Borehole 1 and 2) were on the slope to the southwest of the graben and another one (Borehole 3) was to the south of it.

As a result, each of the borehole loggings showed that there was no sign of slip surface of natural landslide such as clay and slickenside. In addition, they revealed the same southward discontinuity set at the angle of approximately 35 degrees, which originated from the bedding planes. On the other hand, the degree of rock mass weathering showed a significant difference between the southwest slope and the south one; that is, the southwest slope consists of fresh rock classified as very strong rock in geotechnical engineering, while the south one is composed of highly weathered rock categorized as weak rock. These results suggest that the south slope is prone to a planar failure, whereas the southwest slope is not.

In conclusion, there are few possibilities for a landslide caused by tunnel excavation in this slope. Namely, the southwestward rock slide is unlikely to take place due to the strong rock and the difference between the dip direction of the bedding planes and the slope, even though there is a graben. The other possibility is that a southward planar failure could potentially take place in the weak rock, however, it wouldn't be caused by the excavation, as the distance between the tunnel and the estimated slip surface from the graben is sufficient. However, monitoring this slope during the tunnel construction is strongly recommended to avoid any risks.

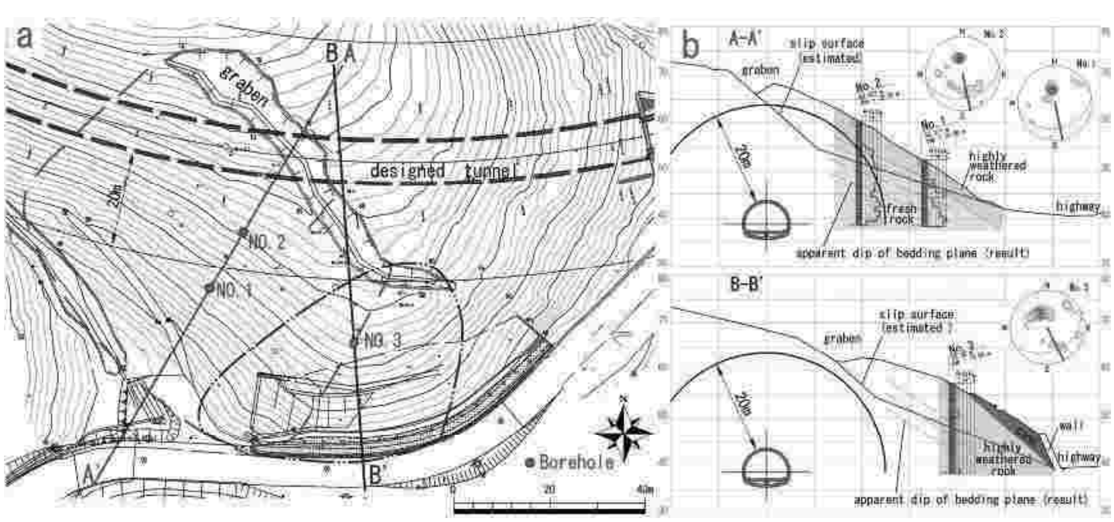


Fig. 1, Contour map of the slope (a) and cross sections (b; A-A' and B-B')

Experimental investigation of sediment resuspension and redeposition process by shoaling internal solitary waves on uniform slope

Zhuangcai Tian [1], * Xiujun Guo [1,2], Yonggang Jia [1,2], and Le Yu [1]

[1]*College of Environmental Science and Engineering, Ocean University of China, Qingdao, P. R. China*
[2]*Shandong Provincial Key Laboratory of Marine Environment and Geological Engineering, Qingdao, P. R. China*
**Corresponding author: guojunqd@163.com*

Shoaling internal solitary waves (ISWs) may erode, resuspend and transport sediments, first towards shore by boluses, and subsequently offshore through the generation of intermediate and bottom nepheloid layers. However, no one could confirm this mechanism and study resuspended sediments showing how to deposit in recent studies. To address these questions, we used flume experiments to examine idealized situations of sediment resuspension, transport and deposition caused by shoaling ISW packet. By analysing the changes of the suspended sediment concentration and slope elevation on uniform slope, we found the following conclusions: two offshore spreading intermediate nepheloid layers were formed in clayey silt experiment. The upper nepheloid layer was thicker than the lower nepheloid layer, and its concentration was lower. The suspended sediment mainly redeposited in the wave-breaking position. It is a potential role for the development of sand waves. About 50% of suspended sediment offshore spread by INL along continental shelves to the basin. Our study would be helpful to carry out new field experiments designed to obtain direct measurements of sediment resuspension, transport and redeposition caused by shoaling ISWs.

Fault trace investigation of the blind segment of the Sanyi Fault, Central Taiwan

***I-Chin Yen[1,2], Yueh-Iuan Ko[3], Yen-Chyun Liu[4], Jin-Wei Hsu[4], Shih-Ting Lu[4], Wen-Jeng Lee[1], and Piao Lee[5]**

[1]Graduate Institute of Applied Geology, National Central University, Taoyuan, Taiwan (R.O.C)
[2]YIC Geological Office, Penghu, Taiwan (R.O.C.)
[3]Sinotech Construction Corporation, LTD., Taipei, Taiwan (R.O.C.)
[4]Central Geological Survey, Ministry of Economic Affairs, New Taipei, Taiwan (R.O.C)
[5]United Geotech, Inc., Taipei, Taiwan (R.O.C.)
**Corresponding author: ichin.yen@gmail.com*

The Sanyi Fault, the reversal active fault, extends about 30 km along the foothill and the Taichung Basin in central Taiwan. The fault trace of the Sanyi Fault has been covered by the Holocene deposits along the lower river terrace and Taichung basin, which is a blind segment of the fault without displaced landform. In this study, we investigated subsurface fault trace by using boring data and Resistivity Image Profiling Method, and established the subsurface geological profiles across the fault trace.

As resulting, 13 study drilled wells and 4 cross-sections were completed in Houli and Fengyuan area. The first cross section (P1) was located nearby the Taian Station in Houli Township. The cores obtained from 2 drilled wells had no fault core because of shallow drilling. We uses Resistivity Image Profiling Method to investigate the subsurface material along P1 cross-section to indentify the location of the fault. In the river course of te Tachia River, the outcrops of the Sanyi Fault display distinct fault zones. The attitudes and the width of the fault zones are N0°E/40°S and 30 m, respectively. The fault gouge and breccia can be observed in the fault zones. In the south of the Tachia River, the Sanyi Fault cuts the gravel deposition of Holocene. The branch faults also resulted in scarps in the hanging wall of the Sanyi Fault.

The other 3 cross-sections are located in Fengyuan District. The cross sections P2 includes 4 boreholes that are located in the northern area of Fengyuan. The cores composed of laccolith are obtained from all of drilled wells that indicate the hanging wall of the Sanyi Fault. The cross sections P3 with 3 boreholes is 1.5 km away from P2 in south. The eastern 2 boreholes (wells 3A and 3C) drilled into bedrock, and the cores composed of Holocene alluvium are obtained from the well in west (3B). Therefore the Sanyi Fault is inferred between well 3B and 3C. The cross section P4 which included 4 boreholes is located in the southern Fengyuan urban area. The similar core descriptions of the profile P4 indicates that the fault is situated between wells 4B and 4D.

According to the subsurface geological profiles, the fault zone character and distribution in the subsurface of the blind segment of the Sanyi Fault are interpreted.

Characteristics of the Chekualin Fault in the Yanchao Area, Southern Taiwan

***Ding Chuan, Chengchou Lee, and Shuiken Ho**

Sinogeotech, Taiwan
**Corresponding author:dabeain@sinogeotech.com.tw*

The study area is located in Southwestern Taiwan located at the junction by the Hsinhua Hill in the east and Chianan Alluvial Plain in the west (Lin, 2013). The Chekualin Fault is one of those active reverse faults that strike NNE~NE around study area and expose the Late Pleistocene Strata both hanging-wall and footwall. According to field survey, the attitudes of bedding plane in hanging wall of the Chekualin Fault are N30~55◦E/40~90◦SE and the outcrops often show dense fault zones, whereas in footwall are N0~20◦E/25~50◦ NW, and is relatively flat with no apparent fault zones. Study area is located at southwest of this fault trace, which is covered by Holocene terrace and alluvium deposits.

The purpose of this study is to detect (i) where does the Chekualin Fault extend in the junction between hill and plain area, (ii) how does it form, and most importantly (iii) what is the fault activity. A salient lineation with ENE strike exists between the Gunshuiping and the Qiaotou areas, and its flexural scarp, which is 1~3 m high and extends c.a. 3.5 km long with dextral displacement, might be formed by the Chekualin Fault according to the continuation of the fault and identification by boreholes data in this study. The downthrown side of the flexural scarp is situated in the north and the upthrown side in the south. East of the Gunshuiping area, the lineation is ambiguous due to erosion.

According to the localities of the Chekualin fault discovered by drilling data, this lineation is probably connected to the locality of south-western part of the Chekualin Fault trace. Inclined electric poles, ground surface and building cracks, etc. usually represent the results of crust deformation due to the activity of faults. These abnormal phenomena mentioned above around study area were largely formed by a belt-like zone along the Chekualin Fault traces. The results imply unequal crustal uplifting by the activities of the Chekualin fault which might be the main reason causing abnormal inclined poles, building and ground surface cracks.

There are 5 layers from the bottom to the top by drill cores: Layer A (bedrock) mainly consists of thick-bedded, massive mudstone, intercalated with sandstone, often showing significant dense shear zones dominated by ductile deformational mechanism, thick-bedded fault gauges and fault breccia. Layer A belonged to NN19a~≧NN16 zone (c.a. 0.65 ma~≧3.12 ma) as suggested by the results of nano fossil analysis. Layer B ~ D (Holocene marine deposits) consisted of alternate sand and mud, intercalated with massive mud and thin layered gravels at the bottom. There are abundant carbonaceous materials, some vivianites, shells, foraminifera, charcoals, debris of coral reefs and deformational structures. These were formed in ca. 5,000~10,000 cal yr BP. Layer E consisted of back-fill deposits.

Geological drilling profiles show clear differences in occurrence from hanging wall to footwall. The fault plane of the Chekualin Fault tilts to the south and dips c.a. 80 degrees. This fault not only cuts through the bedrock but also has deformed the young alluvium. The strike of this fault is ENE when the localities of the Chekualin Fault in two sites are connected, and the fault might be connected to the lineation.

Average long-term crustal uplift rates of the Chekualin Fault are calculated according to eustatic sea level, the depth of paleo environment and calibrated ^{14}C age (cal yr BP). The result suggests that the Chekualin Fault was active since 10,000 yr and resulted in the uplift of crust unequally both sides of the fault. The maximum rate 3.8±0.9 mm/yr (BH-7_30.25 m) is located at hanging wall but the minimum rate 0.4±0.7 mm/yr (BH-11_43.85 m) is located at footwall.

REFERENCES

Lin, C.W., 2013, Explanatory Text of the Geologic Map of Taiwan scale 1:50,000: Qishan Sheet, Central Geological Survey, MOEA, pp. 1–93.

Relationship between earthquake distribution characteristic and present-day tectonic stress magnitudes around the Korean Peninsula

Inho Soh, and *Chandong Chang

Department of Geology, Chungnam National University, Daejeon, Korea
**Corresponding author: cchang@cnu.ac.kr*

We characterize present-day tectonic stress magnitudes using earthquake focal mechanism solutions (FMS) around the Korean Peninsula and attempt to relate them with the distribution of earthquakes. Relative magnitudes of the three principal stresses and their orientations are provided by inverting multiple FMS (Gephart and Forsyth, 1984; Michael, 1984). Also, we combine the relative stress magnitude parameter (R-value) derived from the inversion process and the concept of frictional equilibrium of stress state defined by Coulomb friction law in order to estimate absolute magnitudes of the stresses.

Using 152 FMS data (magnitude ≥2.5) in the Korean Peninsula (Fig. 1), the stress inversion conducted at regularly spaced grid points yields a consistent strike-slip faulting regime. The result shows that the maximum (S1) and the minimum (S3) principal stresses act in horizontal planes (with an S1 azimuth in ENE-WSW) and the intermediate principal stress (S2) is close to vertical. However, R-value varies from 0.28 to 0.75 depending on locations, systematically increasing eastward. Based on the R-values and stress regime, and using a value for vertical stress (Sv) estimated from the overburden weight of rock, together with a value for the maximum differential stress (based on the Coulomb friction of faults optimally oriented for slip; Sibson, 1974), we estimated absolute magnitudes of the two horizontal principal stresses. Our estimation of the stress magnitudes shows that the maximum horizontal principal stress (S1) normalized by vertical stress tends to increase from 1.3 in the west to 1.8 in the east (Fig. 2).

As a result, faulting events around the Korean Peninsula are characterized in such that normal faulting events are densely populated in the west region where the horizontal stress is relatively low, whereas numerous reverse faulting events prevail in the east offshore where the horizontal stress is relatively high (Figs. 1 and 2). This distinct clustering of faulting types in different regions is compatible with the estimated variation of stress. Such a characteristic distribution of distinct faulting types in different regions can only be explained in terms of stress magnitude variation. Moreover, this variation appears to be related to differences in the rigidity of crustal rocks.

REFERENCES

Gephart, J.W. and Forsyth, D.W., 1984, An improved method for determining the regional stress tensor using earthquake focal mechanism data: Application to the San Fernando Earthquake Sequence. Journal of Geophysical Research: Solid Earth, v. 89, pp. 9305–9320.

Michael, A.J., 1984, Determination of stress from slip data: Faults and folds. Journal of Geophysical Research: Solid Earth, v. 89, pp. 11517–11526.

Sibson, R.H., 1974, Frictional constraints on thrust, wrench and normal faults, Nature, v. 249, pp. 542–544.

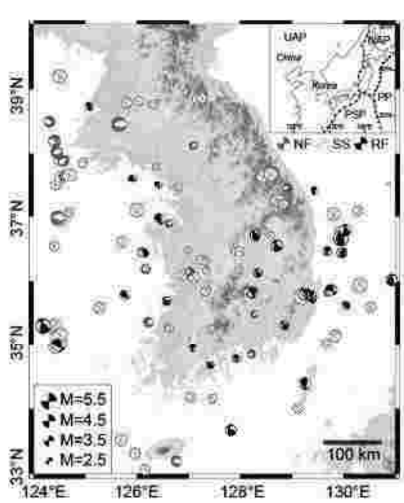


Fig. 1, FMS around the Korean Peninsula

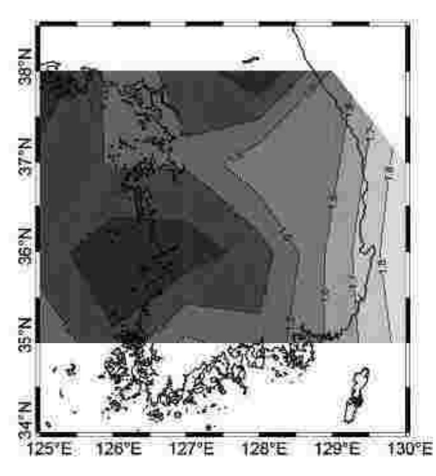


Fig. 2, Spatial Variations in Magnitude of the Maximum Horizontal Principal Stress (S1)

Mapping and characterization of Badi Gad Fault, an active strike-slip fault of the Lesser Himalaya, on the basis of petrological and microstructural studies in Ridi-Shantipur area of Gulmi District, West-Central Nepal

***Manish Singh Chaudhary, and Kabi Raj Paudyal**

Central Department of Geology, Tribhuvan University, Kirtipur, Kathmandu, Nepal
**Corresponding author: geo.c.manis@gmail.com*

The Nepal Lesser Himalaya is a fold- and thrust- belt with complex stratigraphy and structures. Petrological and microstructural studies were carried out along the Ridi-Shantipur area of Gulmi District, West-Central Nepal with the aim to locate the Badi Gad Fault precisely. For that geological mapping was carried out covering about two topo-sheets in 1:25,000 scales. Attention was given to map the micro-structures developed in the rocks. Study area consists of the rocks of the Nawakot Group of the Lesser Himalaya. These rocks are mapped under the Nourpul Formation and the Dhading Dolomite. The Nourpul Formation is conformably overlain by the Dhading Dolomite with shear contact in most of the parts. The Nourpul Formation further can be divided into three members viz. the Lower, the Middle and the Upper from bottom to top respectively. The Lower Member consists of pelitic phyllite and metasandstone with sub-ordinates of quartzite and calcareous beds, the Middle Member is composed of siliceous pink dolomite with sub-ordinates of grey phyllite and the Upper Member consists of alternate succession of pelitic phyllite, metasandstone and pink quartzite in varying proportions. The succession of the Dhading Dolomite consists of bluish grey siliceous dolomite with some pelitic partings where the dolomite has abundance of dome and columnar stromatolite. A number of folds, faults and shear zones have been mapped in the area. Mostly two types of folds trending to N-S and E-W are found. Axes of these folds are plotted and its deformation history was studied. Eksingau shear zone is one of the large shear zone so far mapped in the area. This shear zone is indicated by well-developed fault gauge, breccias, spring lines and deep-seated active landslides. A number of other shear zones are mapped adjacent to this shear zone. The extension of these shear zones represent the presence of the Badi Gad Fault in the area. One major thrust, the Harewa Khola Thrust is also mapped along the NW of the area.

Microstructural study shows that the rocks in the Ridi-Shantipur area has undergone intense as well as multiple deformation. Swelling and pinching boudinage and veins and cross cutting features among them show multiple deformation and slip movements in the quartz veins indicate that Badi Gad Fault is a dextral strike-slip fault. Analysis of small scale structures indicates four phases of deformation history in the study area. First two D1 and D2 phase shows the Pre-Himalayan trending N-S. Second two D3 and D4 phase shows the Himalayan deformation trending nearly E-W of the area. Petrographic study of the rocks has supported the deformation studies. Overall studies are found useful to locate and precisely map the Bad Gad Fault, a source of hazards in the area.

The study on the shear zone of plane less fault, in Neogene sedimentary beds in Miura Peninsula, south of Tokyo

***Takao Chaishi[1], and Toru Arai[2]**

[1]*JP Design Co. Ltd.,*
[2]*Geo Science Research Co. Ltd.*
**Corresponding author: Chaishi@jpde.co.jp*

Consolidated sheared zone in mainly sedimentary or volcanic rocks sometimes show features such as sheared zone having breadth consolidated than both side matrix rocks and protruded from the rocks due to its resistance of erosion. This sheared zone is often observed in the low consolidated rocks like sandstone. It is revealed that these consolidated sheared zones are formed by strain hardening or slip hardened faulting. When grains of loosely packed unconsolidated high porosity rocks are undergone shear deformation, rocks altered to fine particles and rearranged under the condition of confining stress. The strength increases as the result of grain size reduction and poorer sorting, and tightly packed condition. On the other hand, strain softening decreases strength of fault plane after shear deformation.

These consolidated shear zone of the fault are often found in the area of young sedimentary or volcanic beds in Japan arc island. Tertiary formations are distributed in the Miura Peninsula, south of Tokyo. It is well known that many minor fault systems are observed in this formation and so called plane less faults or consolidated faults. We investigated these fault systems with the view point of consolidated shear zone. The Misaki Formation is of middle to late Miocene age of the lower part of the Miura Group, and is mainly composed of the alternating of tuff with scoria and tufaceous siltstone. It is inferred that most of these formations will be accretionary prism of Neogene ocean plate. Beds of the Misaki Formation dip with 10 degrees to 20 degrees, partly over 50 degrees. Four fault systems, oldest reverse system A and younger three normal or lateral slip fault systems are classified and interpreted by previous researchers.

Reverse fault system clearly cuts the alternating beds of scoria and tufaceous siltstone. Consolidated shear zone with a few cm breadth in the scoria layers which protrude from the rocks and plane less with thin breadth in the siltstone layers along the same fault plane are clearly observed (Fig. 1). The structure shows that the consolidated shear zone is formed in scoria layer of coarse grains by strain hardening phenomenon, and thin shear plane is formed in the siltstone of fine grains by strain softening phenomenon under the same shear stress and surrounding confined pressure. These two different type features of the same fault are so called plane less fault in a wide sense. Therefore, low consolidated comparatively coarse rocks are deformed by strain hardening and fine rocks with clay mineral are deformed by strain softening under same depth and confined stress. These reverse fault systems will be formed after the folding structures of the Miura Group because of difference of estimated principal compressive stress axis directions of both structures. We report the case of completely different features of shear zone and shear plane of the same plane less fault, from field observation in this paper.

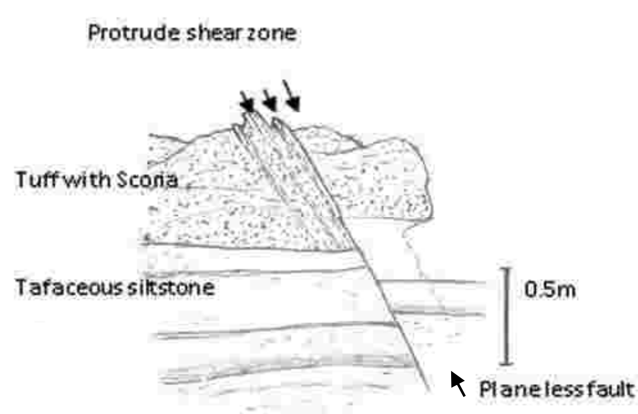


Fig. 1, Sketch of the shear zones and plane less fault

Paleo-seismic archive in the Kathmandu Basin sediments: an assessment of seismic hazard scenario in the Central Himalaya

***Ananta P. Gajurel[1], and Tetsuya Sakai[2]**

[1]*Department of Geology, Tri-Chandra Campus, Tribhuvan University, Kathmandu, Nepal*
[2]*Department of Geosciences, Shimane University, Matsue-shi, Japan*
**Corresponding author: apgajurel@gmail.com*

Soft-sediment deformation structures formed during ground shaking motion triggered by earthquake are archived in Kathmandu basin sediments at its upper part. The upper 30-40 m thick sediments were deposited in lacustrine, delta front and delta plain environments from 50 Ka to 10 Ka. The soft sediment deformation structures like flame structures, ball-and-pillow structures and sand dykes associated with small scale faults are termed as seismites. Extensive field work in the northern part of the Kathmandu basin provides opportunity to detail and map the upper part of basin-fill sediments that exposed in sand quarry areas. The soft-sediment structures have been recorded according to their stratigraphic position in the field and the age of the deposits have also been constrained by carbon-14 dating from organic matter of the sediments. Frequent occurrence of centimeter to meter scale such structures provide paleo-seismic activities and help to assess seismic hazard scenario in the central Himalaya. In this presentation, we detail these structures and explore the paleo-seismic activities.

Geological and engineering geological study of Imja Glacier Lake and its adjoint area, Eastern Nepal

***Keshav Jaisi[1], and Kabiraj Paudyal[2]**

[1]Nepal Government, Ministry of Irrigation
[2]Central Department of Geology, Tribhuvan University, Kathmandu, Nepal
**Corresponding author: jaisikeshav1@gmail.com*

Glacier Lake Outburst Flood (GLOF) is a potential disaster of Nepal. Recent reports have indicated that glaciers continue to retreat worldwide as a result of contemporary warming trends. Twenty-four new glacial lakes have formed and thirty-four have grown significantly during the past 50 years in the Mt. Everest region of Nepal. Imja Thso, located in the Khumbu region of Nepal (27.9^o N, 86.9^o E), has been investigated for more than 20 years. The lake has experienced particularly rapid growth in area and volume since the early 1960's, leading to concern over the risk of a catastrophic GLOF event. Imja Lake is thought to be among the most dangerous glacial lakes in the Khumbu region. A very few work is carried out to study glacier lakes and their damming moraine in Nepal in the past. This dissertation work is based on the geological and engineering geological study of moraine dams in the Imja Glacier Lake of Eastern Nepal. The study concerns about selection of one of the best channel alignment for the construction of open cannel in surface to lower the water level by minimizing the risk of possible failure of dam. For that surface condition of buried ice, seepage areas, material type and distribution, strength of individual materials and instabilities survey were carried out and an engineering geological map was prepared. Imja Glacier Lake was surrounded all side by loosely compacted moraine materials. The size of moraine materials ranges from pebble to boulder size with various composition. For the suitability of construction materials for proposed engineering structure, a construction materials survey was carried out in the field and soil samples were collected for the lab tests. Based on surface condition, size and distribution, composition, strength, instabilities survey and lab result of end moraine materials of Imja Glacier Lake, suitable alignment for construction of open channel is recommended.

Investigation of liquefaction susceptibility at different shaking level in Kathmandu Valley

***Deepak Thapa[1], and Narayan Parsad Marasini[2]**

[1]M. Sc. Program in Earthquake, Department of Civil Engineering, Thapathali Campus.
[2]National Society for Earthquake Technology-Nepal (NSET)
**Corresponding author: nmarasini@nset.org.np*

The Kathmandu Valley, capital city with rapid urbanization. Population is about 2.5 Million. The valley comprises the part of three districts namely Kathmandu, Lalitpur and Bhaktapur covering area of 570 km^2. Not only the capital city it is a cultural and political hub of Nepal. The Kathmandu Valley is bowl-shaped composed mainly of sand, silt and clay layers with shallow depth of water, which is highly suitable condition for the occurrence of liquefaction. The Kathmandu valley lies in a very active seismic zone. Several big earthquakes have impacted the city in the past. There is also evidence of soil liquefaction during the big shaking in the past. In the Recent, April 25, 2015 Gorkha earthquake, there was seen sign of liquefaction at different places like Imadol, Bungmati, Ramkot, Jharuwarashi, Hattiban, Duwakot and Manamaiju although the shaking level (160 gal KANTP) was low to induce liquefaction. Peak ground acceleration (PGA) is the most important parameter for liquefaction potential analysis. In this study, soil liquefaction is evaluated at different shaking level in terms of the factor of safety against liquefaction (FS) along the depth of soil profiles using available Standard Penetration Test (SPT) data. The assessment of liquefaction risk is evaluated at 175 representative sites in valley using the bore hole records from Standard Penetration Tests. Liquefaction Potential Index (IL) was determined to predict the potential of liquefaction to cause damage at a site. The factor of safety against liquefaction (FS) predicts what will happen to a soil element, the IL predicts the performance of the whole soil column and the consequence of liquefaction at the ground surface. Thus, Liquefaction Potential Index (IL) is the more reliable index to describe the severity of liquefaction potential at any location. Spatial distribution of Soil Liquefaction Potential Index (IL) is presented in the form of Susceptibility maps at different ground shaking level of 0.1g, 0.2g, 0.3g, 0.4g and 0.5g.

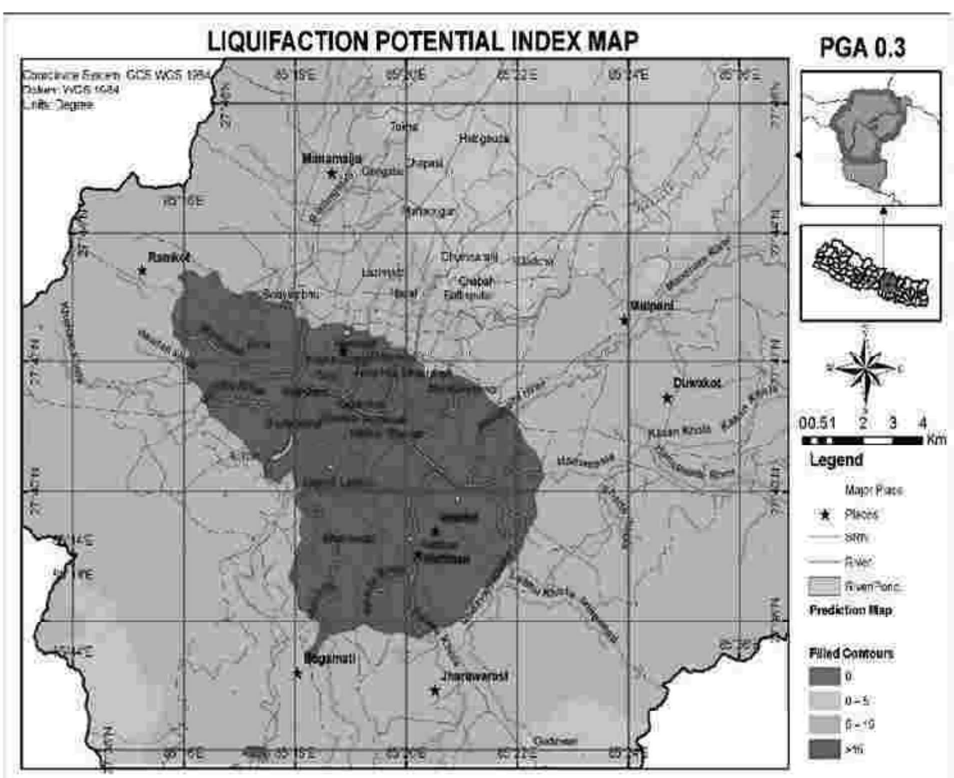


Fig. 1, Liquefaction Potential Index Map at PGA 0.3 g

Observation of the total number of fractures in Toba Caldera to discover potential of phreatic type eruption from Mount Toba

***Faris Primayudha, Choirul Risman, Muhammad Ali Akbar, Rifqi Aditya, and Safira Nurul Imani**

Geology Study Program, FMIPA, Universitas Indonesia, Depok, Indonesia
**Corresponding author: faris.lienandjaja@gmail.com*

The explosive eruption of the Toba Volcano formed a caldera with dimensions of 100 km long and 30 km wide. Due to a dimension of its caldera, it can be interpreted that Toba Volcano has a large volume of a magma chamber. The caldera was formed and then filled with meteoric water created the Toba Lake. The supply of water in the Toba Caldera can cause accumulation of pressure due to the accumulation of steam from the heating of water by magma. If the pressure continues to accumulate, it can trigger a phreatic type eruption. There has been an increase in the intensity of earthquake activity in the Toba Lake area. This event causes increase in potential for phreatic eruptions caused by water heating on fractures resulting from earthquakes. Identification of the fractures and monitoring of the Toba Volcano are possible to reduce the potential of the fatality in the case of an eruption. Measurement used in this research are thermocouple, pH meter, seismic data, and DEM interpretation. The aim of this research was to discover the sum of fractures, predict and calculate whether eruptions would occur, intending to reduce the risk of disaster. There are some fractures that have potential to cause disaster in the form of a phreatic eruption, coupled with data from monitoring result of the Mount Toba showing that it is still active with the existence of fumarole. From these data, disaster mitigation should be possible to reduce the risk of disaster victims.

Tsunami boulders and its implications on the mega earthquake potential along Ryukyu Archipelago, Japan

***Ömer Aydan[1,2], and Naohiko Tokashiki[3]**

[1]University of the Ryukyus, Department of Civil Engineering, Nishihara, Okinawa, Japan
[2]Disaster Prevention Research Institute for Islands Region
[3]Research Institute of Crustal Engineering and Disaster Prevention, Japan
**Corresponding author: aydan@tec.u-ryukyu.ac.jp*

The Ryukyu Archipelago is situated on the Ryukyu Arc and consists of a chain of islands for a length of 1300 km between Kyushu Island of Japan and Taiwan. The main islands are Amami-Oshima, Okinawa, Miyako, Ishigaki, Iriomote and Yonaguni from the north to the south. The Ryukyu Arc is considered to be a convergent plate margin where the Philippine Sea Plate is subducting beneath the Eurasian Plate (Fig. 1; Kizaki, 1986). The arc is a rifting fragment of continental crust and it is oriented NE-SW and the convergence rate between the Philippine Sea Plate and the Eurasia Plate varies from 5 to 7 cm/year.

Tectonic evolution since the Neogene is divided into three stages. Stage 1 (Late Miocene) is pre-rift sedimentation. Stage 2 (Early Pleistocene) is the initial back-arc rifting. Stage 3 (Holocene) is the back-arc rifting still in progress. The age of the basement is pre-Cenozoic and the basement rocks consist of chert and schists. Cenozoic sandstone, shale and limestone. The Ryukyu trench in east and Ryukyu trough in west overlay the basement rocks. These rock units are followed by Pliocene Shimajiri Formation and all formations are covered with the Quaternary Ryukyu limestone and Holocene deposits.

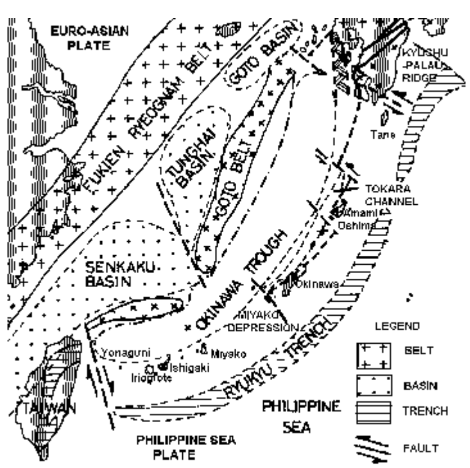
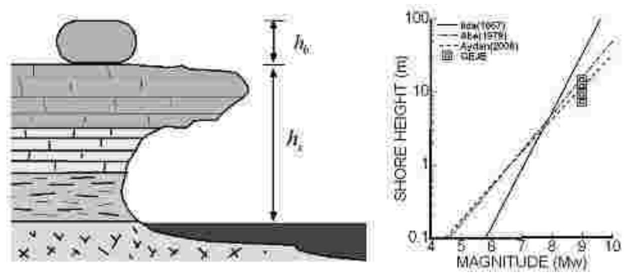


Fig. 1, Tectonic features of Ryukyu Islands and their close vicinity (modified after Kizaki, 1986)

The authors made observations on large tsunami boulders in Okinawa, Miyako, Shimojiri and Ishigaki Islands (Fig. 2). Although these tsunami boulders were initially believed to be due to the 1771 Meiwa earthquake with an estimated magnitude of 7.4, the recent studies indicated that they were much older. Particularly, the tsunami boulder in Shimoji Island is probably the largest in the world. Aydan (2008) developed some empirical relations between the magnitude of great earthquakes and tsunami height at shoreline (Fig. 3). The estimated magnitudes of earthquakes with the consideration of position of tsunami boulders are shown in Table 1. The results clearly indicate that mega-earthquakes are possible along the Ryukyu Archipelago and disaster-prevention measures must take this fact into account.

(a) Ishigaki (b) Shimoji (c) Miyako

Fig. 2, Views of tsunami boulders in Ryukyu Archipelago



(a) (b)

Fig. 3, (a) Illustration of shore height vs tsunami boulder height and (b) Empirical relation between magnitude and shoreline height

Table 1: Estimated magnitude of earthquakes from elevation and height of tsunami boulders

Location	Elevation (m)	Height (m)	Mw (Lower Bound)	Mw (Upper Bound)
Miyako-Hennazaki	20	4	9.5	9.7
Shimoji	12.5	9.0	9.0	9.5
Okinawa-Kasakanca	12	3	9.0	9.2
Ishigaki-Ohama	8.0	5.9	8.6	9.1

REFERENCES

Kizaki, K., 1986, Geology and tectonics of the Ryukyu Islands. Tectonophysics, v. 125, pp. 193–207.

Aydan, Ö., 2008, Some Thoughts on Seismic and Tsunami Hazard Potentials in Indonesia with a special emphasis on Sumatra Island. Journal of The School of Marine Science and Technology, v.6, no.3, pp. 19–38.

Probabilistic damage assessment of strong earthquake scenarios in Koyna region, India

*** S. M. S. Prakash Dev[1], and R. Nagarajan[2]**

[1]*Centre of Studies in Resources Engineering (CSRE),*
[2]*Indian institute of Technology Bombay – 400076, India*
**Corresponding author: smspdev@gmail.com*

Koyna area is located in the stable continental region (SCR) of Peninsular India. Generally, SCRs have low seismicity, however Koyna region has been seismically active ever since the strong earthquake of M6.5 (1967) which killed about 200 people and damaged properties. Though, initially, earthquakes in Koyna were attributed to reservoir induced seismicity (RIS), but there was no evidence/correlation between the reservoir operations and seismic events. The possibility of tectonic influences on seismicity is being considered for any seismic hazard assessment. Hence, the objective of the study is to assess damages from strong earthquake event scenario.

Peak ground acceleration (PGA) was estimated using reported seismic events spread over 398 years for five linear sources of earthquake as an input to Probabilistic seismic hazard analysis (PSHA) of the region. The estimated bedrock level (site condition class B) PGA-values for various return periods (years) for scenarios (> M6.6 has return period of 400 years) in 50 years 0.21g (500yrs) for soil-regolith thickness for different site conditions; lateritic sites (class C) show 0.41(500yrs) and soil sites (class D) show 0.82g (500yrs) respectively.

The estimated damage potential of the anticipated >M6.6 in 50 years at 10, 20 and 30 kms are 38-35%, 35-32%, 32-29% (MMI-VII) and 8-7%, 7-6%, 6-5% (MMI-VIII) respectively. This information was spatially projected for disaster management services. The paper discusses on the above said aspect.

Volcaniclastic stratigraphy of Tangkuban Perahu Volcano and how it is used to predict the future hazardous eruption

***Abriyanto Putra S. N., Aji Ahmed M., Kevin Estonio, Maria Johana M. W., Raihan Zidan I., and Twin Hosea, W. K.**

Geology Study Program , FMIPA, Universitas Indonesia, Depok, Indonesia
**Corresponding author: abriyantoputrasn@gmail.com*

The Tangkuban Perahu, West Java (Indonesia), located 34 km from the city of Bandung, is one of the densest areas on the island of Java. Therefore, research on the history of eruption and the potential threat to living things around the Tangkuban Perahu is very important because small eruptions can endanger the lives of living things and infrastructure. The Tangkuban Perahu is a stratovolcano-type volcano which means the result of eruption can be either lava or pyroclastic. Periodic eruptions can be measured based on the thickness and volume of the eruption results. The Tangkuban Perahu was made from the Pra-Sunda and the Sunda Mountain which is a supervolcano, therefore causing the eruptions very powerful. Research on the Mount Tangkuban Perahu needs to be done to prevent and minimize casualties as well as economic losses because of the eruptions. Research on the magnitude of the eruption of the Mount Tangkuban Perahu can be done through aspects of volcanostratigraphy, which deals with a stratigraphic measurement from the eruption of mountains that have been piled up, settled, and become stones.

Volcanostratigraphy treats the erupted material as a sediment so that the layers can be measured. Volcanostratigraphy of the Tangkuban Perahu has been showing eruption deposits from time to time. The current study focuses on volcanic material deposition from the age of the Holocene to determine the direction of the flow of lava, lahars, and pyroclastic materials.

Asperity models for earthquakes based on co-seismic displacements

***Zhengfang Li, and Bengang Zhou**

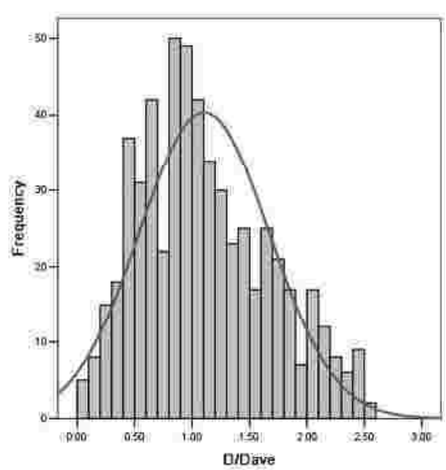
Key Laboratory of Active Tectonics and Volcano, Institute of Geology, China Earthquake Administration, Beijing 100029, China
**Corresponding author: lizhengfang07@163.com*

Asperity models can be used to describe heterogeneities of the rupture plane of the fault as an earthquake source (Kanamori et al., 1978). This work follows such an idea that an asperity is defined as a region in which the slip is larger by a prescribed amount than the average slip over the entire fault (Somerville et al., 1999). Because co-seismic displacements along a surface rupture zone depend on slip on the subsurface fault, we attempt to construct asperity models for a seismic source in terms of such displacements observed on the ground. Using data of 10 major events in western China, we made a statistical analysis to distributions of co-seismic displacements on surface rupture zones, yielding a series of ratios of maximum displacements to the average ones in intervals on the rupture (Fig. 1a). Then, upon the lower and upper limit values of these ratios, we inferred the asperities along the rupture zones and analysed further the relationships between asperity parameters, rupture geometries, and earthquake magnitudes based on real data of more earthquakes (Fig. 1b). Finally, we used the data of the 2001 Kunlunshan Ms 8.1 event to test this approach for construction of asperity models.

REFERENCES

Kanamori, H., and Stewart, G. S., 1978, Seismological Aspects of the Guatemala Earthquake of February 4. J. Geophysics Res., v. 83, pp. 3427–3434.

Somerville, P. K., Irikula, R., Graves, Sawada, S. et al., 1999, Characterizing Crustal Earthquake Slip Models for the Prediction of Strong Ground Motion, Seism Res Lett. v. 70(1), pp. 59–80.



(a)

(b)

The probability ratio of overall asperities to the whole surface rupture zone is：

$$F((D/Dave)_{\max}) = \int_{1.0}^{(D/Dave)_{\max}} \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(D/D_{ave}-\mu)^2}{2\sigma^2}} d(D/Dave)$$

The probability ratio of maximum asperities to the whole surface rupture zone is：

$$F((D/Dave)_{\max}) = \int_{1.5}^{(D/Dave)_{\max}} \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(D/D_{ave}-\mu)^2}{2\sigma^2}} d(D/Dave)$$

Fig. 1, Histogram of D/Dave values from 10 great earthquakes (a), and asperities along the rupture zones and asperity parameters (b)

SMRM field work platform for rock engineering

Jie Wu

Zhongke Ji'ao Geo-engineering Consultant Co.Ltd
No19, Beituchengxilu, Beijing, 100029, China
E-mail: wufaquan@mail.iggcas.ac.cn

In China, especially the southwest China, over 50% infrastructure construction projects are built on or in rock mass, including electronic project, mining project, railway and highway project and slope projects. Due to the unpredictable structure in rock mass, field investigation reduces the uncertainty effect in construction process.

Combining with software design, we developed series of devices to enhance the efficiency of field work. Multifunctional point load tester is finishing developing recently. It can measure both point load strength of rock and joint friction angle. For software, it composed of Android APP and Winform software. It provides statistic methods (SMRM) to calculate varies representative parameters and describe the characteristic of rock mass in adjacent areas.

Stabilization of Cliffs over the Road EN 379-1 Arrabida natural park, Setubal, Portugal

Ricardo Oliveira

COBA and New University of Lisbon, Portugal
E-mail: r.oliveira@cobagroup.com

The national road EN-379-1 is the main access from the town of Setubal to several beautiful Atlantic beaches of great touristic value. The road is located at the foot of the southern slope of the Arrabida Mountain (500 m high), running along the base of abandoned sea cliffs, consisting mainly of Jurassic limestones.

These steep rock slopes are prone to frequent rock falls of different sizes, putting at risk the circulation of the road, namely during summer time when the large number of vehicles and people increase the risk of serious accidents.

Because of this, the Portuguese Road Authority decided, in 2004, to close the road to all kinds of traffic. COBA, Consulting Engineers, was then charged of studying the integral stabilization of the slopes of this section of the road, in order to reduce the inherent risks to acceptable limits, taking into consideration that no large excavations were accepted, as consequence of all the mountain being a Natural Park.

The proposed design considered that imposition and the technical solutions were mainly reinforced mesh, dynamic and rigid barriers, rock bolting and anchoring, retaining walls and a false tunnel, privileging the minimization of the environmental impact of the works.

The road was closed during 2 years, until August 2006, and the construction of the proposed solutions, in difficult conditions, proved their adequacy until today.

A calibration test of karst sinkhole collapse monitoring device by Optical Time Domain Reflectometry (BOTDR) technique

*** Zhen-de Guan, and Xiao-zhen Jiang**

Institute of Karst Geology, CAGS，,Qixing50 Road Guilin, GuangXi ,china.
**Corresponding author: guanzd@karst.ac.cn*

Brillouin Optical Time Domain Reflectometry (BOTDR) is a distributed fiber optic strain sensing systems based on Brillouin scattering. This technique may potentially become a useful tool to monitor and predict karst collapse, especially for linear infrastructure such as roads, highways, and railways (Tang et al., 2006). This paper introduces a calibration device which is used to establish the relationship between fiber deformation and underlain soil-cave dimension. Based on the deformation characteristics of the sinkhole collapse, the mechanical relation between soil body and sensing fiber was analysed, and a simplified model of collapse was proposed for testing design. The experimental tests were carried out through the designed equipment to investigate the effect of the sinkhole's size and the overburden stratum's thickness on embedded optical fibers.

As soil void develops, incumbent soil load and void scale are critical to the magnitude and distribution of the stress around the developing void. According to the key monitoring factors and the deformation compatibility between fiber and soil, collapse mechanic model was simplified and collapse simulation experiment system was designed. During the formation of soil voids, the friction imposed on optical fiber at the edge of void and its influence area are changeable. Thus, optical fiber fixation should be considered in the model design. Intertwist, one of the fixation methods, is adopted which can express the way how friction varies with loads effectively (Fig.1).

Firstly, the sinkhole formation process was stimulated with the orderly changes in load on the optical fiber. Secondly, the impact of the changes of sinkhole size on the sensing fiber monitoring was analysed. It shows from the experiment results that the strain change in the sinkhole formation process can be monitored by distributed optical fiber sensing technology and the sinkhole size can be reflected through the optical fiber strain range. Besides, the sensibility of coated optical fiber in sinkhole collapse monitoring tests varies between different types of optical fibers. Due to the effective response of the distributed optical fiber sensing technology to sinkhole forming and evolving, it can be adopted in the monitoring for potential sinkhole collapse.

REFERENCE

Tang T., Zhu Y., and Caid E., 2006, Experimental research and rock sliding monitor of optical fibre sensing. Chinese journal of Rock Mechanics and Engineering, v. 25(2), pp. 340–344.

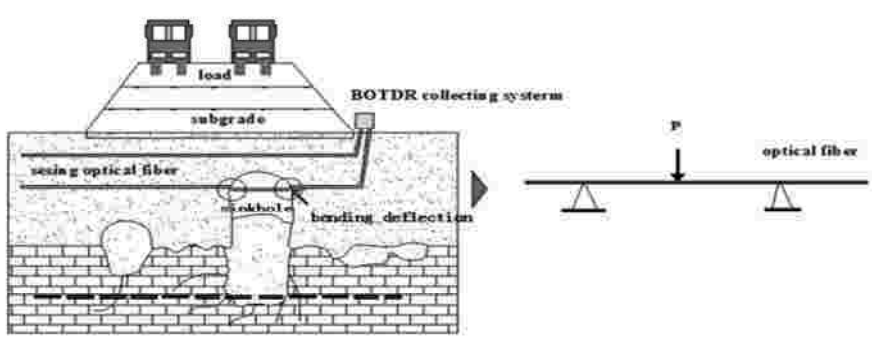


Fig. 1, Simplified karst sinkhole model

Journal of Nepal Geological Society, 2017, Vol. 54 (Sp. Issue)

Landslide countermeasure and maintenance of slope surface of highway adjacent to the Median Tectonic Line

***Hironobu Itoh[1], Junji Uchida[1], Kohei Minami[1], Shinji Sakai[2], and Yuhei Nishikawa[2]**

[1]*West* Nippon Expressway Engineering Shikoku Co. Ltd
[2]*West Nippom Expressway Co. Ltd.*
**Corresponding author: hironobu.ito@w-e-shikoku.co.jp*

This report introduces large scale landslide measures, variations and maintenance examples adjacent to the Median Tectonic Line located in the Hanazono area located between the Tokushima Expressway Ikawa Ikeda interchange and the Mima interchange (Fig. 1).

The Tokushima Expressway Hanazono area is a district where repeated deformation occurred during construction stage and operation stage, and its counter measures were taken each time.

As we planned to cut on the Median Tectonic Line, we decided to cut the alluvial fan of gravelly soil formation and the fault crush zone clay, the deformation continued over a long period of time.

As for countermeasures against deformation, the soil removal has not been made because there was a tower of mobile phone on the top of the cutting slope and there was not enough time before opening to. As a result, the countermeasures were for ground anchors and drainage wells.

The topography of the Tokushima Expressway Hanazonoarea is located in Mino-Cho, Mima City, Tokushima Prefecture, nearly parallel to the Yoshinogawa River along the southern rim of the Sanuki Mountain Range, and cutting the Mino Fault which is the active fault of the Median Tectonic Line was done.

The Mino fault is located on the northern coast of the Yoshinogawa River from Mino to Mima, there are four formations: 1) Izumi Group at the late Mesozoic era Cretaceous period as the basement rock 2) Dotyu Formation at the Pliocene to the Middle Pleistocene 3) late Pleistocene middle rank and the lower terraced sediments, and 4) Holocene alluvial stacks are distributed.

The geology consists of the fan-shaped gravel formation at the Cenozoic Quaternary and Izumi Group mudstone dominant formation at the Mesozoic Cretaceous as shown in Fig. 1. It is between which there is partly degraded fault fracture madstone.

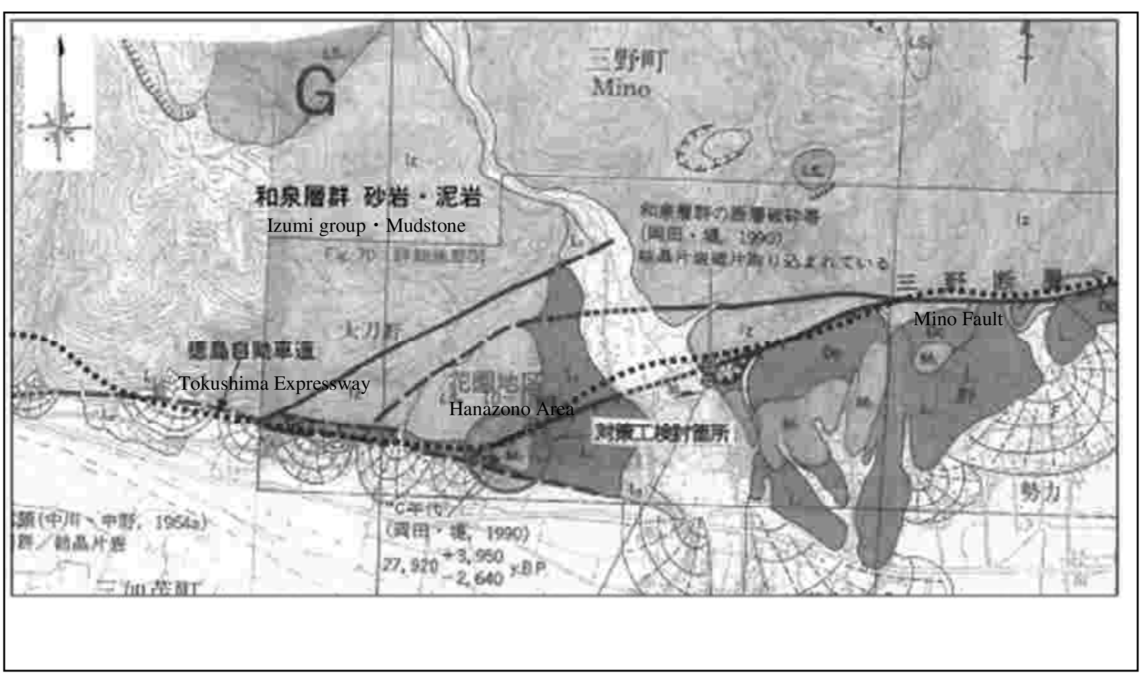


Fig. 1, A geological map

Geoenvironmental vulnerability to exogenous geohazards upon risk assessment and mapping

***Irina Kozliakova, OlgaEremina, PavelIvanov, and MariaKomarevskaya**

Sergeev Institute of Environmental Geoscience Russian Academy of Sciences (IEG RAS), Moscow, Russia
**Corresponding author: kozlyakova@rambler.ru*

In urban areas, the assessment and mapping of geological hazards without taking into consideration the urban infrastructure appears to be low informative. In large cities, the losses from geological processes are almost equally controlled by the scope and intensity of geohazard manifestation as well as by the density and type of urban infrastructure load. The important task of geological studies in urban areas involves the transition from the assessment and mapping of hazards produced by the exogenous geological processes to the assessment and mapping of risk, which will give us the most adequate idea about the scope of the possible damage caused by the manifested geohazards. At present, virtually all researchers try to assess the geological risk in urban areas by combining the maps of hazardous natural processes with vulnerability maps. The vulnerability is taken to mean the property of a system or an object to lose its capacity to perform the designated mission as affected by geohazards. Different approaches to assess the vulnerability of territories and infrastructure objects are proposed (Blong, 2003; Koff et al., 2006; Zhang et al., 2006; Mimouni and Djafri, 2008).

By the example of Moscow megacity, we have developed the general methodology for urban territory ranking by its vulnerability to exogenous geological processes (such as landslides, karst-suffosion processes, and waterlogging) to be used at the stage of general urban development plan). The procedure of vulnerability analysis consists in the estimation of housing density, its type and age, as well as the type of impact of exogenous geological processes on urban environment. For the purpose of this investigation, we have suggested to take the urban environment as the object at risk to mean the city territory with its on-surface buildings. We have performed typification and zoning of Moscow urban environment by its vulnerability to exogenous geological hazards at a scale of 1:50 000.

The areas of low vulnerability include recreational park and forest-park zones with low building-up density as well as the territories occupied by modern unique engineering structures involving the subsurface and built using the engineering protection measures. The areas of moderate vulnerability include the territories occupied by the modern multi-storey residential and office buildings mainly with piles and plate foundations designed with the consideration of geological hazards. The areas of high vulnerability involve industrial zones and the residential zone built up with 5-12-storey houses dating back to the beginning and the middle of the 20th century with strip, more rarely, pile foundations. The areas of very high vulnerability encompass the historical center of Moscow with abundant architectural monuments and partially restored historical buildings.

The specifics of geohazards impact on urban environment is analysed for each type of areas, and the concept of forming risk of economic loss is formulated. The known cases of deformations and ruining buildings were taken into account, as well as the expenses for reconstruction and reclamation at the sites of processes manifestation, expedience and cost of building reconstruction, etc.

REFERENCES

Blong, R., 2003, A new damage index, Nat. Hazards, v. 30(1), pp. 1–23.

Koff, G.L., Likhacheva, E.A., and Timofeev, D.A., 2006, Geoecology of Moscow: methodology and methods of assessing the urban environment state. Moscow, Media-Press, (in Russian).

Mimouni, O. and Djafri, F.W., 2008, Use of GIS for Geotechnical and geological major risks mapping of Bab-Ez-Zouar, OuedSmar, dar-El-Beida, Rouiba and Hamiz areas. In: Proceedings of II European Conference of IAEG, Madrid, Spain, 15-19 September 2008 “Cities and their Underground Environment”.

Zhang, F., Yang Q., Jia, X., Liu, J., and Wang, B., 2006, Land-use optimization by geological hazard assessment in Nanjing City, China, Engineering Geology for Tomorrow’s Cities. IAEG, 6-10 Sept. 2006, CD-rom, paper no. 4-324.

Mapping geological risk upon the underground linear construction in megacities

***Irina Kozlyakova, Nadezhda Anisimova, Olga Eremina, and Oleg Mironov**

Sergeev Institute of Environmental Geoscience RAS, Moscow, Russia
**Corresponding author: kozlyakova@rambler.ru*

Geological risk as the qualitative or quantitative measure of geological hazard or a complex of hazards established for a certain object in the form of possible absolute or relative economic losses (damage) is the function of affecting hazard(s) value and the vulnerability of engineering structure. The risk of probable losses for a particular engineering structure in the course of its construction and operation may be comparatively analysed for different types of engineering geological conditions distinguished in the area proceeding from the assessment of geological hazards that affect the engineering structures, since the vulnerability of engineering structure to these geological hazards is taken as a constant in this case (Koff et al., 2006; Kozlyakova et al., 2015). The qualitative characteristics of possible damage from geological hazards within the area with engineering geological conditions of a certain type serves as the risk index. According to this approach, the procedure of assessment and mapping includes the following steps (Fig. 1):- the geological structure and hydrogeological conditions in the bottom, walls, and roof of the tunnel are obtained for its particular depth from the 3D model of the geoenvironment;

- engineering geological conditions are typified and the impact of geological hazards on the linear structure is analysed for each type of engineering geological conditions;

- possible damages during the construction and operation of the tunnel are identified;

- the comparative qualitative categories of risk are distinguished and substantiated;

- the risk map is compiled.

According to the developed procedure, the map of geological risk upon the construction and operation of shallow (a depth of 20 m) tunnels was compiled to a scale 1:100,000. The territory of Moscow enclosed within the Moscow automobile ring road was taken as a representative case, for which the 3D model of geoenvironment has been created. The possible damage was assessed proceeding from the analysis of such hazards as groundwater and quicksand outburst in the construction pit, suffusion, and karst-suffosion processes affecting the building structures. Very high geological risk arises upon the construction and running tunnels in water-saturated sandy grounds, which is proved by many negative cases in cutting shallow tunnels in Moscow.

REFERENCES

Kozlyakova, I.V., Mironov, O.K., and Eremina, O.N., 2015, Engineering Geological Zoning of Moscow by the conditions for subsurface construction, Proceedings 12th IAEG Congress, Turin, Italy. Springer, v. 5, pp. 923–926.

Koff, G.L., Likhacheva, E.A., and Timofeev, D.A., 2006, Geoecology of Moscow: methodology and methods of assessing urban environment state. Moscow, Media-Press.

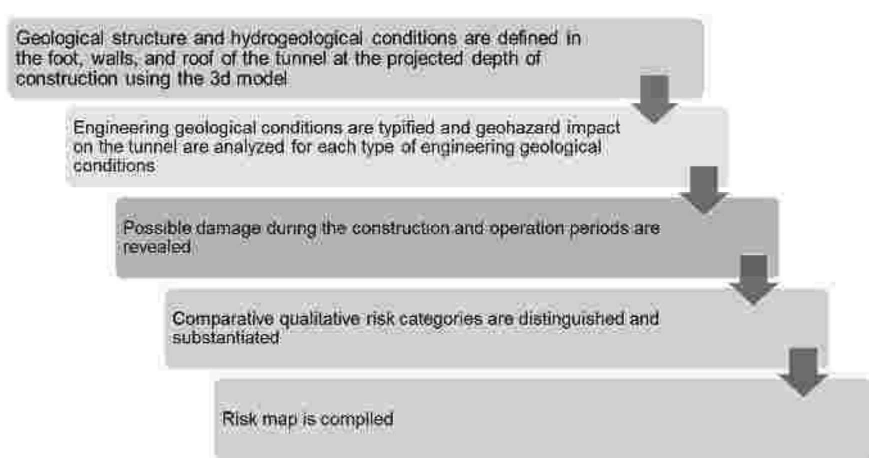


Fig. 1, Procedure of assessment and mapping geological risk for the future underground construction of linear structures

Building a more resilient Nepal: the utilisation of the resilience scorecard for Kathmandu, Nepal following the Gorkha Earthquake of 2015

***Michael R.Z. Whitworth[1], Mathew Francis[2], Shaun Hubbard[3], and Judy Mitrani-Reiser[4]**

[1]*AECOM Mayflower House, Armada Way, Plymouth, U.K.*
[2]*AECOM 756 East Winchester Street, Suite 400, Salt Lake City, Utah, U.S.*
[3]*AECOM Level 2, 2 Hazeldean Road, Addington, Christchurch, New Zealand*
[4] *John Hopkins University, Baltimore, U.S.*
**Corresponding author: michael.whitworth@aecom.com*

At 11:56 NST (06:11 UTC) on the 25 April, an earthquake with a magnitude of 7.8Mw struck Nepal. The earthquake killed almost 9000 people, injuring over 22,000. More than 500,000 houses, 8,000 schools, and 400 health facilities have been totally destroyed. There has been a significant impact on the infrastructure including landslides that have affected major transport routes. In addition, Nepal is severely affected by monsoons and is identified as one of the most susceptible countries to the impacts of climate change. Kathmandu, the capital of Nepal is a key driver for economic growth and is currently undergoing rapid urbanisation, with an increase in population of over 5 million in the last decade.

The disaster resilience scorecard is based on the “Ten Essentials” defined by the United Nations International Strategy for Disaster Reduction for making cities resilient and has been developed by AECOM and IBM. It has been successfully adopted to cities around the world including: Salt Lake City, US; Bandung Indonesia; Coimbatore, India; Puerto Montt, Chile; Makati, Philippines; Quelimane, Mozambique and Pemba, Mozambique.

The scorecards intention is to establish a baseline measurement of the current level of disaster resilience, to identify priorities for investment and action, and to track progress in improving disaster resilience over time. It consists of 85 disaster resilience evaluation criteria. Each evaluation criteria is broken down to set out the aspect of disaster resilience being measured, an indicative measurement and the measurement of scale (from 0 to 5 where 5 is best practice).

The opportunity exists to utilise the UN Resilience Scorecard to assess the current level of preparedness of Kathmandu. The assessment undertaken forms a baseline assessment addressing core infrastructure issues from the earthquake and evaluating core community functions. The assessment appraises 3 core components based on the 10 pillars of the scorecard:

1. The disaster cycle: From preparedness through response recovery to developing risk scenarios.
2. The operational capacity of the financial, governmental and societal institutions.
3. The resilience of the society from Urban to Remote including infrastructure and natural buffers.

Based on field visits to Kathmandu and the surrounding areas undertaken following the April 2015 earthquake, an initial high level assessment of 4 of the 10 pillars of the resilience scorecard has been undertaken. This identifies that Kathmandu has a low score of between 1 and 2 based on the preliminary findings. Of particular note is the susceptibility of critical infrastructure to natural hazards including many essential road routes and the impact of the earthquake on schools and hospitals despite an earthquake design code being in use in Nepal.

Further work is required to complete a comprehensive assessment for all 10 pillars of the scorecard, establish a base line to enable prioritisation of actions future development and reconstruction efforts. In conjunction with the Nepal government it is hoped that this can be completed and will help to form a baseline with which to monitor earthquake reconstruction with the aim of not only building a more resilient Kathmandu, but also Nepal.

Journal of Nepal Geological Society, 2017, Vol. 54 (Sp. Issue)

Unexpectedly residential house collapse: A case study of urban hazard in Dhaka City, Bangladesh

***Mohammad Feruj Alam, Munir Hossain, and Md Azahar Hossain**

Geological Survey of Bangladesh, 153 Pioneer Road, Segunbagicha, Dhaka-1000, Bangladesh
**Corresponding author: ferujgsb@yahoo.com*

The investigated area falls under Rampura area in Dhaka North City Corporation, Bangladesh. The study has been carried out for an urban hazard analyses to find out the engineering geological characteristics of subsurface sediments and causes of tin shed two storied house unexpectedly and suddenly collapsed and submerged in the Rampura valley on the 15 April, 2015. The study was conducted by Google Earth and Global Land Survey (GLS) Satellite image analysis, field investigation, conversation with local people, rescue team and journalists, geotechnical borehole and laboratory analysis. The collapsed house was made by tin, corrugated iron sheet, bamboo poles and concrete pillar. At least 20 families were lived in the house and most of the inhabitants were garment workers. Total 12 people were died due to collapsed. The daily useable items such as fridge, television, furniture etc. were also damaged. The area is covered by valley and the latter is surrounded by Pleistocene terrace and Recent floodplain. The sub-surface deposits of this valley consist of clayey silt, silty sand and sandy silt, respectively from top to bottom. The sediments are enriched in organics from 4 to 15 m depths. Grain size analysis indicates that the sediments are clayey silt from surface to 18.0 m, silty sand from 18.0 to 28.5 m and sandy silt from 28.5 to 30.0 m depths. Atterberg limit test indicates that liquid limit of the collected subsurface sediments varies from 36% to 47%; plastic limit from 25% to 29% and plasticity index varies between 11% and 18%. This indicates that sediments are slightly plastic and low compressibility inorganic silts. Specific gravity of the sediments varies from 2.66 to 2.68. Natural moisture content of the sediments have been observed about 34.5%, dry density about 1.37 gm/cc, wet density 1.84 gm/cc and unconfined compression strength about 45.9 KPa. From this result, it reveals that shallow foundation is not suitable in the area but deep foundation particularly pile foundation would be required. The size, length and capacity of pile would be selected and calculated by the design engineer. In this study, six major possible causes have been identified for this urban hazard incident, and these are (1) presence of a valley, (2) valley deposits, (3) very soft organic clay and soft slightly plastic clayey silt, (4) poor quality construction materials of house and shallow foundation pillar, (5) overloaded by inhabitants with their useable items, and (6) filled up asides of the valley by filling materials which push the pillar of the house. Due to push or additional side pressure by filling materials to the foundation pillar, the pillar moved and imbalanced the total house, and finally house was suddenly subsided and collapsed by uniform settlement. The sedimentological characteristics of the area enhance the procedure. Finally, it can be concluded that geological and engineering geological study must be carried out for an urban hazard analyses in the Rampura valley area as well as other valley areas in Dhaka city for future plan of urbanization and avoiding this type of urban hazard.

Determination of deep subsurface shear wave velocity structure in the central part of the Kathmandu Valley, Nepal using broad band seismograph arrays for long period microtremor

***Mukunda Bhattarai[1], Lok Bijaya Adhikari[1], Bharat Prasad Koirala[1], Dinesh Nepali[2], Santosh Dhakal[2], Suresh Shrestha[2], Toshiaki Yokoi[3], Takumi Hayashida[3]**

[1]*National Seismological Center, Department of Mines and Geology, Kathmandu Nepal*
[2]*Department of Mines and Geology, Kathmandu Nepal*
[3]*International Institute of Seismology and Earthquake Engineering, Building Research Institute, Tsukuba, Japan*
**Corresponding author: mb2058@yahoo.com*

We have conducted microtremor array exploration almost in the central part of the Kathmandu Valley, Nepal where a significant amplification of the long period seismic waves at 0.25–0.3 Hz was observed during the 2015 Gorkha, Nepal Earthquake. Assuming the targeted area of about 3 km as the deepest part of the basin we determined the shear wave velocity structure of deep sedimentary layers for strong ground motion simulation within the framework of ongoing SATREPS/NERDiM project among DMG, UTokyo and JICA. The four seismographs used are consist of the broadband seismometer CMG40T (Guralp) and the digital data logger LS8800 (Hakusan) for exploration as deep as several hundred meters using long period microtremor (ambient noise), the power of which is weak due to a distance as long as 700 km from the nearest coastal line Bay of Bengal, India. Up to Feb. 21 2017, the following three arrays have been performed. First an irregular fan shaped array consist of three deployments was performed at and around the strong ground motion observation site in the office building of Department of Mines and Geology (DMG), Lainchaur. A seismograph was installed and worked for more than three nights at DMG (but the first overnight in a pair) and other three were set for overnight measurement, at different sites every night, within a distance of approximately 1.2 Km situated at Narayanhiti Durbar Museum, Durbar Marg and Nepal Police Headquarter, Naxal (first overnight in a pair) in the single storey buildings or on the open ground and tent during December 2016. Second an array consists of two equilateral triangular deployments and a trapezium one has been deployed inside Singhadurbar an administrative center of Nepal government and also the third one in a scalene triangular shape at and around the natural gas well site of DMG in Teku-Kaimati-Tripureshwor area during February 2017. The Medium and Small regular array data processed in Singhadurbar using Spatial Auto Correlation (SPAC) method showed the isotropic behavior of wave propagation, which supports the applicability of the interferometric SPAC for irregular deployments.

The analysis targeted on the frequency range below 1.0 Hz revealed a simple dispersion curve of Rayleigh waves at Singhadurbar, differently from those at around DMG-Narayanhiti Museum-Police headquarter and Teku-Kalimati-Tripureshwor where the influence of higher mode is suspected.

Construction practices in rural Nepal without consideration of engineering geology

Narayan Gurung

Kadoorie Agricultural Aid Association (KAAA), Pokhara, Nepal
E-mail: jyonus@hotmail.com

A lot of construction works are going on in the rural areas of Nepal. These include basic infrastructure projects such as pedestrian bridges, hydro - electricity, drinking water, school buildings, community shelters, health post buildings, etc. According to reports, at least 350 pedestrian bridges are built every year in Nepal. Similarly, some 200 hydroelectricity projects of up to 200 KW are built annually and similar number of School buildings are built. It costs millions of dollars to build these infrastructure projects. Most rural parts of Nepal are prone to geo-hazards such as landslides, Rock falls, floods, ground subsidence etc. Further, Nepal is prone to earthquakes and it is adding up the geo-hazards' risk further. Sadly, most construction works have been carried out or are being carried out without due consideration of the fact of the fragile geology of Nepal. As a result, these construction works have not been sustainable. This a fact that any project does not long last until its geology is not good or well protected from the possible geo-hazards irrespective of how nicely and strongly one builds the project. To this end, planners, engineers and contractors should understand the importance of engineering geology for the sustainable development.

Estimation of strong ground motion in Yogyakarta, Indonesia, by stochastic Green's function method

***Nwai Le Ngal[1], Junji Kiyono[2], Subagyo Pramumijoyo[1], Iman Satyarno[3], and Kirbani Sri Brotopuspito[4]**

[1] *Department of Geological Engineering, Gadjah Mada University, Indonesia*
[2]*Department of Urban management, Kyoto University, japan*
[3]*Department of Civil and Environmental Engineering, Gadjah Mada University, Indonesia*
[4]*Department of Geophysics, Gadjah Mada University, Indonesia*
**Corresponding author: nwai.nln@gmail.com*

The Yogyakarta Earthquake (Mw = 6.3) occurred in May 27, 2006, killed 5,716 people and injuried 37,927. Although the magnitude of the earthquake was not so large, the damage was extremely high because 15,664 and 202,032 houses were totally destroyed and partially damaged, respectively. In this study, the simulation of strong ground motion was done by using stochastic Green's function method of Irikura and Miyake (2011). The location of the earthquake 6.3 Mw (7.962°S–110.458°E, depth 10 km) reported by USGS was used.

The source of the earthquake was modelled by a simple rectangular fault of which size was 20 km x10 km. The depth of the fault was assumed to be 10 km under surface. The fault plane was divided into 50 rectangular subfaults with 2 km x 2 km in each and each subfault was represented as a point source. Amplification of surface layers was linearly taken into account.

The accelerations of strong ground motions obtained range from <400 cm/s^2 to >700 cm/s^2 as shown in Fig. 1. The simulation results can be futher applied to an input for slope stability analysis, landslide run-out estimation and response sepctrum analysis of structure.

REFERENCES

Irikura, K., and Miyake, H., 2011, Recipe for Predicting Strong Ground Motion from Crustal Earthquake Scenarios. Pure and Applied Geophysics, v. 168, pp. 85–104. doi:10.1007/s00024-010-0150-9.

Irikura K., Miyake, H., Iwata, T., Kamae, K., Kawabe, H., and Dalguer, L. A., 2004, Recipe for predicting strong ground motion from future large earthquake. In Proceedings of the 13th World Conference on Earthquake Engineering No. 1371.

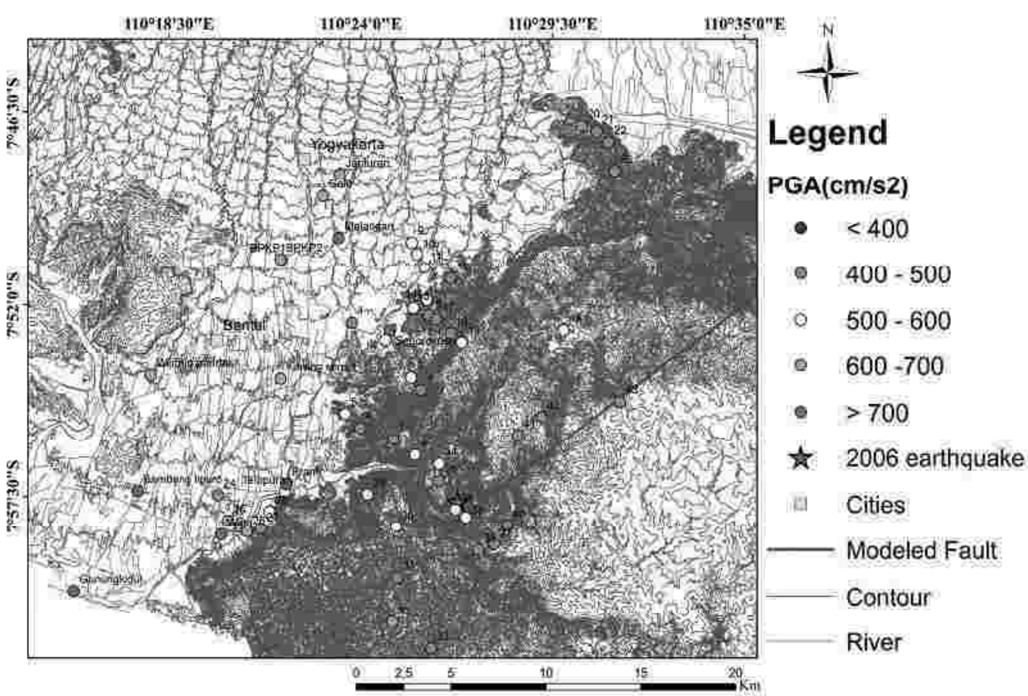


Fig. 1, Peak ground acceleration distribution map of the study area

Assessment of exogenous geological hazards in Moscow

***Olga Eremina, and Irina Kozliakova**

Sergeev Institute of Environmental Geoscience Russian Academy of Sciences (IEG RAS), Moscow, Russia
**Corresponding author: sci-council@geoenv.ru*

Sustainable urban development of Moscow is based on the balance between ecological and social-economic demands, rational nature use and improvement of ecological situation. Exogenous geological processes exert a significant impact on the geoecological state of urban area, because being wide spread they complicate substantially the construction and running of buildings and engineering structures. Intensification may pose a real danger to their stability and even to human health and lives.

Assessment of exogenous geological hazards is usually taken to mean outlining the areas of exogenous geological processes (EGP), development and establishing the parameters of EGP manifestation on the earth surface or in the ground massif. The processes are regarded as hazardous, in case their manifestation exerts a negative impact on human vital activity. In urban areas, providing the safe running of existing engineering infrastructure and optimizing the projected disposal of new buildings and structures, it appears to be the main purpose of geohazard assessment. Research methods depend on the scale of research. The probabilistic statistical research methods as well as field observation of processes can be hardly used in urban areas. Urban territory is constantly subjected to surface levelling, and the data about the surface manifestation of EGP are far from being complete there (Osipov, 2007). For the city area or its large districts, the hazard maps are compiled, whereas analytical calculation methods are used for individual buildings and engineering structures. For projecting linear transport structures or large multi-functional complexes, these methods are sometimes combined; i.e., the regions differing in EGP development conditions are outlined on a map, scenarios of possible EGP manifestation are suggested for these regions on the basis of the analysis of engineering geological conditions, the calculation model is built, and the level of possible EGP manifestation is determined. The integral assessment of EGP and its depiction in the map represents a substantial part of geoenvironmental assessment of urban area upon planning its development (Osipov, 2015). Assessment of individual EGP types in Moscow may be exemplified by the “Map of hazard of ancient karst forms and modern karst-suffosion processes” built to a scale 1:10000 (Kutepov et al., 2010). Criteria for distinguishing hazard categories of ancient karst involves duration and intensity of karst process, and the degree of calcareous rock karstification. Criteria for distinguishing hazard categories of current karst-suffosion processes involve the presence of their manifestation on the earth surface and the specific structure of ground massif overlying the carbonate deposits. The maps of exogenous geological processes for the urban area permit us to point out geohazards that should be taken into consideration already at the stage of planning construction and choosing allocation of engineering objects. At the next stage, the dimensions of possible EGP manifestation may be predicted using the existing technologies and proceeding from the results of previous engineering geological survey.

Lately, the particular attention is paid to the assessment of natural-technogenic hazards upon the subsurface development. Special technologies and procedures of this assessment are under development now. Karst and suffusion hazard is also assessed upon the projecting of new metro lines in Moscow. The procedure of this assessment may be shown by the example of the so-called Third metro circle segment from Khoroshevskaya station to Nizhnyaya Maslovka station. This segment crosses the area, which has been long ago known to be subjected to karst and suffusion collapses.

The paper will dwell on the technique of exogenous geological hazard assessment in Moscow; it will describe the main problems arising upon this assessment and the possible ways of solving them. The paper cites the data obtained by the researchers at the laboratory for exogenous geodynamics and geological risk analysis, IEG RAS.

REFERENCES

Kutepov, V.M., Anisimova, N.G., Eremina, O.N., Kozhevnikova, I.A., and Kozlyakova, I.V., 2010, Large-Scale Geological Mapping for Assessing Karst and Karst-Suffosion Hazard in Moscow, Proceedings of the 11the IAEG Congress "Geologically active", Auckland, New Zealand, Sept.5-10, 2010, Taylor and Francis Group, London, pp. 2031–2035.

Osipov, V.I., 2007, Urbanization and natural hazards: The problems to be solved. Geoekologiya (Environmental Geoscience), no.1, pp. 3–9 (in Russian).

Osipov, V. I., 2015, Large-scale thematic geological mapping of Moscow area. G. Lollino et. al. (eds) Engineering Geology for Society and Territory. Springer International Publishing Switzerland, v. 5, pp. 11–16.

Engineering geomorphology of river basin in Central East Nepal

***Ranjan Kumar Dahal, and Suman Manandhar**

[1]*Central Department of Geology, Tribhuvan University, Kirtipur, Kathmandu, Nepal*
**Corresponding author: geosuman27@gmail.com*

The research work has been carried out along the river basin in Central East Nepal. Representative engineering geomorphic features and their engineering challenges have been identified along the B.P. Highway and Khurkot area of Sindhuli District of Nepal. The overall area represents Kuncha Formation of Lesser Himalayan Zone intercalated with gritty phyllite and quartzite along with occasional limestones and gneiss. The river basin formed by Sunkoshi River is suffered through numerous ancient mass movements due to mega earthquakes in Midlands. Huge mass movements at Nigalepani Danda of Sindhuli District and along the left bank of the Sunkoshi river in Khurkot area resemble earthquake induced palaeo mass movements. The characteristics of these mass movements in these areas leaves no distinct drainage pattern on the slope together with sparse vegetation and the hummocky geomorphic features. This type of geomorphic features strongly support the area of earthquake induced mass movements together with joint analyses of displaced masses when compared to scarps. It was noteworthy to understand that many mega and large earthquakes hit the Lesser Himalayan region and their damages signature are still recorded in the slopes of the Midlands however the age of such earthquakes are unknown.

On the other hand, the geomorphic feature of soil deposits on the right bank of the Sunkoshi River at Ghumaune Chainpur addresses evidence of mega earthquake induced landslide dam on the downstream part of the Sunkoshi River at Khurkot area. The debris flow formed fluvio-lacustrine deposit on the top together with various sizes of granitic boulders along with metasandstone, schist, phyllite and occasional amphibolites. The pebble imbrication measured along the road section shows the flow direction towards southwest.

Since infrastructure development such as, road transportation plays vital role to connect two different districts and people, nowadays it is imperative to incorporate road tunnel in terms of safety, economic and time management. Recent road alignment along the palaeo landslide mass takes 40-45 minutes from Khurkot of Sindhuli District to Manthali of Ramechap District and it has several geohazard related problems. The tunnel can reduce 13 minutes travel time and it can also help to reduce geohazards along the roadside slopes from Khurkot to Manthali The engineering geological investigation shows about 5 km of inverted v-shaped tunnel alignment from Khurkot to Kunauri at the gradient of 0.5^{o} on both portals will be one of the best options for the area in which the centre of the tunnel should be kept at about 2.5 km from both portals. The first portal can be proposed at Sunkoshi Bridge in Khurkot and the second portal can be proposed at Kunauri Bazar along the left bank of the Bhalu Khola in Ramechhap District.

Methodical approaches to the assessment of natural risks in urban areas

Valentina Burova

Sergeev Institute of Environmental Geoscience Russian Academy of Sciences, Moscow, Russia.
E-mail: valentina_burova@mail.ru

In megacities, the geological environment is substantially transformed by huge anthropogenic load arising due to high concentration of industrial, civil, administrative, transport, etc. construction, which leads to significant socio-economic losses. At present, the safe urban development may be achieved only on the base of natural risk assessment, which appears to be the main tool mitigating the adverse mutual impact of natural and technogenic environments.

The basic methodical approaches to georisk assessment, including the risk arising in urbanized area, have been developed at the Sergeev Institute of Environmental Geoscience Russian Academy of Sciences. The risk analysis procedure consists of four important interconnected blocks, i.e., the hazard identification, the vulnerability evaluation, the risk assessment, and the risk management.

An urbanized area is a complex technonatural system, within which it appears impossible to distinguish the influence of any particular either natural or anthropogenic factor on the state of buildings and engineering structures for revealing possible adverse consequences. This state is controlled by the combination of natural and technogenic factors, and therefore, risk formation depends directly on the conditions and type of their interaction.

According to the general methodology of natural risk assessment, zoning of the formed risk of losses from geohazards according to the natural and technogenic factors is the main task of georisk estimation in urban areas. This zoning is aimed at distinguishing areas (the final taxons in two-row cross-zoning), within which the risk formation and the related losses follow the definite scenarios. In this case, the scenarios are taken to mean the possibility of developing certain hazardous geological and engineering geological processes and their interaction with the certain technogenic object (hazard recipient), which leads to definite losses, most often in the form of deformation and ruining of buildings and engineering structures.

The final zoning taxons are distinguished by superposition of two independent by their content individual (hierarchical) subsystems of zoning by the principal natural and technogenic factors of risk formation. This zoning suggests a step-by-step subdivision of an urban area into relatively homogenous parts using as a rule one feature in order to outline these parts at each zoning level both by natural and technogenic factors. Thus, we achieve, on one hand, the order in subdividing the whole into parts for each of two factor groups, and on the other hand, the consideration of diverse combination of these factors in setting the final typological taxons.

The degree of deformation or ruining (vulnerability) of buildings and engineering structures as well as corresponding losses may be determined using different modern methodical approaches implying the use of statistical data, modelling, expert estimations, etc. These estimates are necessary for determination of risks (probable economic losses) resulting from the impact of hazardous processes on buildings and engineering structures in urban areas.

Compression behavior of reconstituted clay: a study on Kalomato

***Bhim Kumar Dahal, and Jun-Jie Zheng**

School of Civil Engineering and Mechanics, Huazhong University of Science and Technology, Wuhan, China
**Corresponding author: dahal_bhim@yahoo.com*

Deformation due to load from construction of infrastructure in soft ground is high and sometimes be problematic. The most common method for control of such deformation is soil modification using cement (Broms, 1984). This method is fast, efficient and cheap. In this study, compression and swelling behavior of Kathmandu is studied in undisturbed and reconstituted using Ordinary Portland Cement. In general, the strength of an improved soil increases with the amount of stabilizing agent. The rate of increment in the mechanical property is studied by various researchers in different clay (Kawasaki, et al., 1981; Kamruzzaman, 2002; Horpibulsuk, et al., 2003; Lee, et al., 2005).

The clay sample from Khasibazaar Kathmandu, Nepal is used for the laboratory investigations. The soil is black in color and locally known as Kalomato. This soil is very week and deformation is very high so it is taken as problematic soil for construction of large structure. Reconstituted soil sample were prepared using 5%, 10%, and 15% of cement by dry mass of soil. All the cemented samples were cured at 25°C under atmospheric pressure. Samples were tested after different curing periods to investigate the effect of curing period. The study revealed that cementation effect of natural and reconstituted clay significantly affects the compression behavior of soil. The result of one-dimensional consolidation test (Fig. 1) is summarized in Table 1. Compression and Swelling indices (Cc=0.992, Cs=0.119) of the undisturbed sample is highest among all soil samples. Whereas, remolded sample has lowest compression index (Cc=0.47). Early age cemented soil is more compressible than the fully cured sample but there is no significant different in swelling index. Effect of cement content is observed as the predominating factor for compression behavior of reconstituted soil samples. Higher the cement content higher will be the compression index and primary yield strength of soil on the other hand swelling index is decreased with the cement content.

Table 1: Compression and Swelling index of different soils

Soil		Cc	Cs
Undisturbed		0.992	0.119
Remolded		0.47	0.081
15% Cement	10 Days Curing	0.817	0.037
	28 Days Curing	0.663	0.037
10% Cement	28 Days Curing	0.596	0.048

REFERENCES

Broms, B. B., 1984, Stablisation of soft clay with lime columns. Proceedings, Seminar on Soil Improvement and Construction Techniques in Soft Ground. Sigapore: NanYang Technological Institute.

Horpibulsuk, S., Miura, N., and Nagaraj, T., 2003, Assessment of Strength Development in Cement-Admixed High Water Content Clays with Abrams Law as a Basis. Geotechnique, v. 53(4), pp. 439–444.

Kamruzzaman, A., 2002, Physico-Chemical & Engineering Behaviour of Cement Treated Singapore Marine Clay, PhD Thesis. Singapore: National University of Singapore.

Kawasaki, T., Niina, A., Saitoh, S., Suzuki, Y., and Honjo, Y., 1981. Deep Mixing Method using Cement Hardening Agent. 10th ICSMFE. v. 3, pp. 721–724. 10th ICSMFE.

Lee, F. H., Lee, Y., Chew, S. H., and Yong, K. Y., 2005, Strength and modulus of marine clay-cement mixes. Journal of Geotechnical and Geoenvironmental Engineering, 78–185.

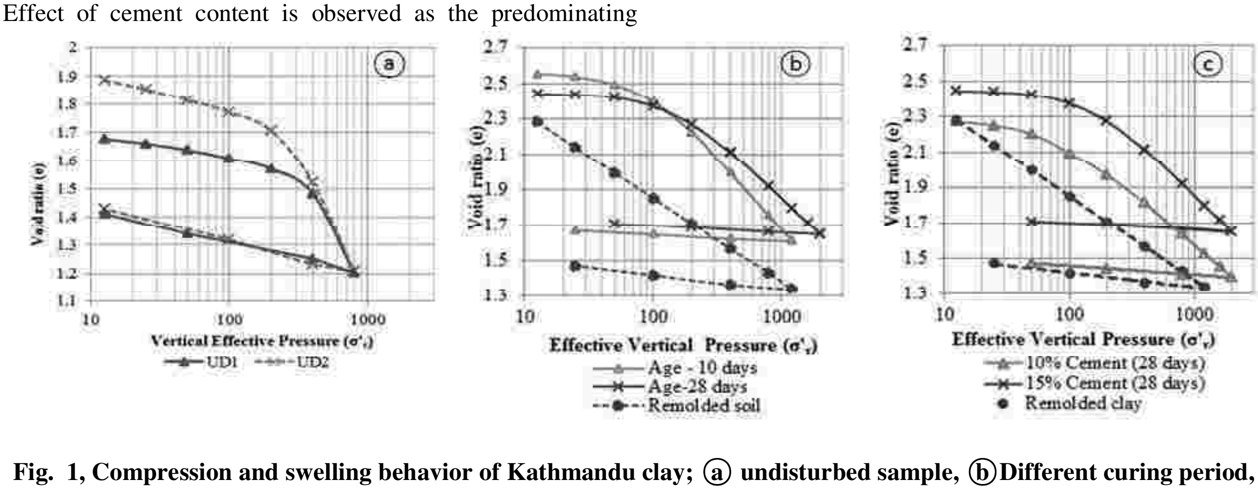


Fig. 1, Compression and swelling behavior of Kathmandu clay; ⓐ undisturbed sample, ⓑDifferent curing period, and ⓒDifferent cement content

Analysis of ground deformation in Sanshandao gold mine based on GPS

***Ma Fengshan, Gu Hongyu, Guo Jie, and Lu Rong**

Key Laboratory of Shale Gas and Geoengineering, Institute of Geology and Geophysics, Chinese Academy of Sciences, Beijing 100029, China

**Corresponding author:fsma@mail.iggcas.ac.cn*

Sanshandao gold mine is the first and the largest mine that has been operating below the ocean in China for a period of at least 25 years. In Recent years, buildings above the mining area have been damaged extensively. Therefore, GPS (with 315 monitoring points) has been used to monitor the ground deformation since 2009 (Fig.1). Ground deformation induced by mining is much more complex in metal mine than coal mine due to the dense joints, high tectonic stress and several intersecting faults. All of the factors were analyzed in this study.

During the process of mining, the value and range of ground deformation were constantly increasing. The results showed that the discontinuous deformation on the surface because of the sliding of F3. There are two motion patterns of F3 during the mining. The two evolution stages of F3 were much important for the deformation and two evolution stages were compressive-shearing motion along the fault plane and, then, tensile-shearing motion. Discontinuous ground deformation along the strike of F3 was especially obvious and would be more serious when mining area trends to the north-east direction. Specifically, the fault step may occur along the strike of F3, especially in the region closing to the edge of mining working. It was also found that the joints of rock mass with steep dip angle contributed the vertical displacement, and the shallow dip angle contributed the horizontal displacement. Meanwhile, high tectonic stress could dramatically enlarge the range of ground deformation, especially in favor of the horizontal displacement. The attitudes of prior joints could contribute to the displacements of rock mass and the high tectonic stress made the ground deformation a stripped shape.

Different characteristics of ground deformation have been recognized and can affect different building structures in different ways. The main reasons for the damages to buildings were the compressive and tensile deformation and the latter were generally more serious as far as structural damage was concerned, while damages to buildings due to slope and curvature were relative slight for the value of them were relative small. Additionally, high risk and potential risk area were identified in this study. Tensile-shearing action through the wall may mainly occur along the strike of F3. Special attention should be paid to the north area of F3 in the future.

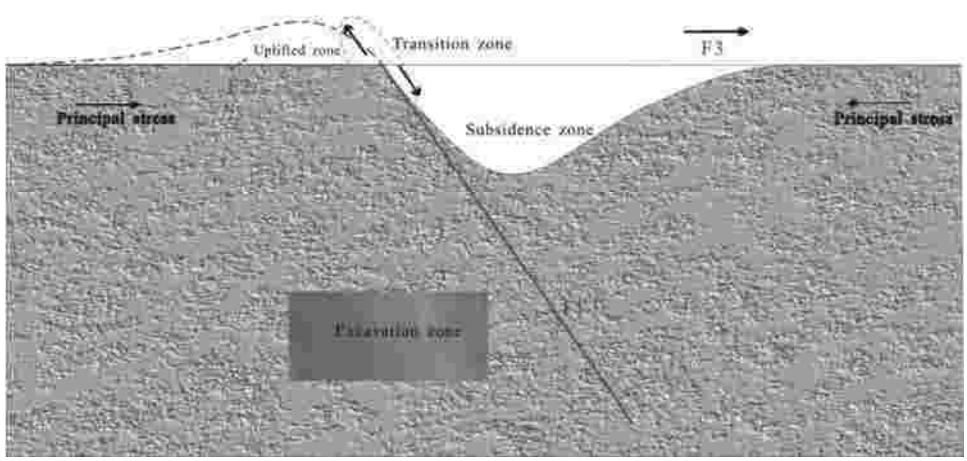


Fig.1, The influence of tectonic stress: uplifted zone and transition zone

Exploration of groundwater resources using Schlumberger arrangement of electrical resistivity survey in Pokhara-Lekhnath Metropolitan City, Kaski District, Nepal

***Hari Ghimire[1], Umesh Chandra Bhusal[2], Rajendra Prasad Bhandari[3], Bhaskar Khatiwada[2], Damu Pandey[4], Shiva Amatya[5], and Mohamed Abdul Kadar Prabhu[6]**

[1]*Explorer Geophysical consultants Pvt. Ltd, Kathmandu Nepal*
[2]*Tribhuvan University, Central Department of Geology, Kathmandu, Nepal*
[3]*Department of Mines and Geology, Nepal*
[4]*Galaxy Services Pvt. Ltd. Kathmandu, Nepal*
[5]*Lekhanath Small Town Water Supply and Sanitation User Committee, Pokhara, Nepal*
[6]*ST Geomative Co. Ltd China, Shenzhen, China*
**Corresponding author: hghimire429100@gmail.com*

Electrical Resistivity Sounding Survey (Schlumberger array) was carried out with the aim of groundwater exploration in Pokhara-Lekhnath Metropolitan City of the Kaski District in Western Nepal. Vertical electrical resistivity sounding was carried out at five locations with maximum current electrode spacing ranging from 500–800 m depending on the availability of the space.

WDJD-4 Multifunction digital resistivity meter was used for data acquisition. Acquired data were analyzed and interpreted using IPI2Win Software. The results of the survey reveal the presence of four to six geoelectric layers.

Top layer comprises of soil with sand and gravels with thickness of layer 1–1.5 m. Second layer with high resistivity value of 3728 Ωm represents highly unsaturated, compacted gravel and boulders layer with thickness around 1 m. The underlying layer with resistivity value ranging from 1000–1880 Ωm revel the presence of highly compacted sand and gravel layer with thickness 20–25 m. The underlying layer with resistivity value 346 Ωm represents saturated sand and gravel layer from depth of 25–100 m from surface. The low resistivity value of 122 m represents highly weathered phyllites. Fresh basement rock has been encountered at a depth of 210–220 m from the surface. This result shows the presence groundwater at a depth of 25–100 m in the area. This result has been verified during drilling of deep tube well based on the recommendation of this study for the exploration and utilization of groundwater for drinking purpose in the area.

Approaches to assessment of the projected tunnel impact on waterlogging and groundwater contamination

***Irina Galitskaya, and Leonid Toms**

Sergeev Institute of Environmental Geoscience Russian Academy of Science (IEG RAS), Moscow, Russia
**Corresponding author: galgeoenv@mail.ru*

The approaches to assessment of the impact on groundwater caused by metro tunnel construction and the examples of these approaches when building a tunnel on the Sokolnicheskaya line of the Moscow metro are discussed. The examples of approaches include the assessment of: 1) groundwater contamination at the construction sites, 2) economic risk of projected tunnel waterlogging.

To determine the possibility of groundwater contamination at the construction sites, at the first stage the following analytical calculations were carried out using the technique (Goldberg, 1987): a) the time of filtration for the most typical pollutants in surface runoff (chlorides, oil products, heavy metals) through vadoze zone, b) changes of pollutants concentrations in the groundwater.

The results of analytical calculations showed that the filtration time of conservative contaminant (chloride ion) consisted for the periods of: snow melting 27 days and intense rainfall - 18 days. Thus, the first aquifer at the study area was unprotected from contamination. However, the entering of most dangerous pollutants - heavy metals and oil products, slows down due to adsorption by the rocks in vadoze zone. When assessing the impact of adsorption on the components migration the following assumptions were made: a) adsorption was described by Henry's linear isotherm, b) heavy metals migration occurred in the absence of strong ligands in solutions. The obtained results showed that the most significant retardation of the migration was characteristic for heavy metals (several centuries). The retardation of oil products migration was less: for periods of snow melting - no more than 380 days and intense rainfall-no more than 250 days. Thus, taking into account the adsorption of the components under consideration, the first aquifer at the study area was poorly protected from oil products contamination and well protected from heavy metals contamination.

According to analytical calculations using the mixing method, the changes of groundwater chemical composition as a result of the entry of chlorides, iron, copper, zinc, nickel and lead with infiltrating waters when constructing a tunnel are insignificant. In contrast, the oil products concentrations increased substantially, reaching values that exceed the maximum permissible value up to 30 times.

At the second stage, vadoze zone flow and the dangerous oil products-benzene and toluene transport modeling were performed with WHI UnSat Suite Plus package (Waterloo Hydrogeologic Ins.). It was found that the concentrations of benzene entering the groundwater level at the end of construction would be 0.40 mg/l, toluene due to lower solubility, greater ability to sorb and volatilize - 0.12 mg /l.

Waterlogging of the tunnel during operation may cause the economic risk. The forecast of groundwater level changes was carried out using numerical simulation to assess the risk of the tunnel waterlogging. According to the obtained results, hydrogeological conditions would change insignificantly and the barrage effect would only manifest itself in the areas where the tunnel was completely submerged in the over-Jurassic aquifer, where, in addition, the tunnel route was projected perpendicular to the flow.

The risk estimation for the case of “non-acceptance of decision” (no waterproofing of tunnel) was performed. The average and maximum values of economic risk as result of waterlogging and full economic costs of waterlogging were estimated. When estimating the risk the total cost of the tunnel was taken as 100%, respectively. All the results of the valuation of risk and loss were expressed as percentages of the projected construction cost. The service life of the tunnel without major repair was 50 years. The risk estimation was carried out using the technique (Recommended Practice, 2002).

At the risk estimating, the following parameters were taken into account: the probability of tunnel waterlogging over the service life period, the duration of tunnel waterlogging, the service life period, the economic vulnerability of the tunnel to the waterlogging, and the cost of the tunnel before affection by waterlogging (percentage). Maximum total economic risk was 0.25%/year. The value of the expected full maximum economic damage to the projected construction for 50 years of its operation consisted 12.5 % of the total cost, which confirmed the importance of waterproofing.

REFERENCES

Goldberg, V.M., 1987, Interrelation between Groundwater Pollution and Environment, Hydrometeoezdat, Leningrad, pp. 187–195.

Recommended Practice for Geological Risk Assessment of Sites in the City of Moscow, 2002, State unitary enterprise of Moscow Department of Economic Research, Informatization and Coordination of Design Works.

Inherent and stress-induced anisotropy of hydraulic conductivity around a rock tunnel-equivalent continuum approach

Huang-Kuei Chu, Po-Sung Lai, and, *Jia-Jyun Dong

Graduate Institute of Applied Geology, National Central University, Taoyuan, Taiwan
**Corresponding author: jjdong@geo.ncu.edu.tw*

The hydraulic conductivity around the disposal tunnel is one of the key parameters for the safety assessment of radioactive waste disposal. This study aims to explore the inherent anisotropy (orientation of the discontinuities) and stress induced anisotropy of the hydraulic conductivity around a rock tunnel. JRC-JCS model is used to estimate the aperture of discontinuities under stress. Based on the calculated stress field via Kirsch solution and the equivalent continuum model, the hydraulic conductivities around a circular tunnel can be calculated. The groundwater inflow of the tunnel is further evaluated via finite difference method. The result shows that the hydraulic conductivity on the tunnel wall is about 1~2 orders of magnitude larger than the one away from the tunnel (or the one of rock mass under boundary stress). The major principal hydraulic conductivity on the tunnel wall can be 6~9 times larger than the minor principal value. The principle directions of the hydraulic conductivity near the tunnel wall are also significantly deviated from the tangential and radial directions when the inherent anisotropy is considered. Groundwater flow analysis shows that the total head and the flow velocity are dominated by the inherent and stress induced anisotropy of hydraulic conductivity. Surprisingly, the inflow of the tunnel is insignificantly influenced by the spatial variation of hydraulic conductivity around the tunnel wall.

Elements of hypogene origin in the karst caves of the Urals (Russia)

Olga Kadebskaya[1], Valerii Kataev[2], Nikolay Maksimovich[3], and *Olga Meshcheriakova[3]

[1]*Mining Institute of the Ural branch of the RAS, Perm, Russia*
[2]*Perm State National Research University, Perm, Russia*
[3]*Institute of Natural Sciences of Perm State National Research University, Perm, Russia*
**Corresponding author: olgam.psu@gmail.com*

Indications of hypogene karst are frequently observed in caves of the Urals. This paper provides a brief overview of them. The Urals occupy an immense territory which lies in four climatic zones and has a complex geological structure. The Urals region is divided into nine geographic areas based on geology, geomorphology, structure and tectonics. (Chibilev 2011, Shakirov, 2011)

Karst features have been studied as part of the natural zoning of the Urals region (Chibilev 2011). In the Urals, virtually all types of surface and underground karst features are present. Rock formations stretch longitudinally, that favors a comparative analysis of processes in karst landscapes in different latitudinal geographical zones. Extensive occurrence of soluble rocks through the area and in the geological cross-section in cratons, folded zones and troughs pre-determined karst development over the long geological history of the Urals. The most intense karstification occurs in Paleozoic sediments.

In the eastern margins of the East European Craton and adjacent parts of the Ural Foredeep, sulfate rocks (gypsum and anhydrite) intercalated with thin beds of limestone and dolomite of the Irenskaya Suite are karstified, and to a lesser extent–limestones and dolomites of the Filippovsky Unit of the Kungurian Stage and limestones of the Artinskian Stage of Lower Permian. Salt-bearing and sulfate sediments occur mainly in the Ural Foredeep. The folded zone of the West Ural and the Central Ural uplifts are characterized by karst development in the Devonian, Carboniferous and Permian carbonate strata of a total thickness of more than 2,000 m. The most intensely karstified is the western slope of the South Urals.

To the date, more than 3,200 caves with the total length of about 244 km are documented in the Urals. Morphological indications of hypogene origin are observed in cavities formed in confined aquifer systems due to the rising groundwater flow through the layers of soluble rocks, and in caves associated with zones of tectonic disruptions. Among suspected hypogene caves developed in carbonate rocks, the most representative are Kizelovskaya-Viasherskaya (7,600 m), Mariinskaya (1,000 m), Sukhaya Atya (2,130 m), Schumiha (1,240 m). Caves of the hypogene origin in sulfate rocks include Vertolyotnaya (1,770 m), Kungur Ice Cave (5700 m), and Ordinskaya (4,900 m).

The largest springs with rising flow (Pymva-Shor, Blue Lake, Kurgazak, Krasny Kluch, Sarva, Sakaska, Berhomut, Tyuba, among others) are associated with the margins of major hydrological basins. Outputs of deep saline waters (sometimes with a high helium content) are documented in the North Urals within the Ural Foredeep (Larevskie Springs), and in the South Urals within the Inzer Synclinorium (Assinsky Springs).

Hypogene hydrothermal cavities, genetically unrelated to the superficial karst topography and local surface recharge, were encountered during the development of the Kizel Coal Basin and the Severouralsk bauxite deposit at depths of more than 2 km.

Hypogene karst processes actively develop in regions underlain by sulfates, carbonates and salt formations throughout the Urals. Even though more than nine thousand publications have been written about the caves of the Urals, there are substantial gaps in understanding of karst evolution such as water exchange conditions, climate, geomorphologic and tectonic history of the territory, and transformation of the soluble formations. Hydrodynamic conditions of confined and unconfined aquifers are ultimately reflected in the morphology of conduits and cavities forming in rocks. Nowadays, we are in the initial stage of the recognition and interpretation of hypogene karst processes and features in the Urals, and further studies are needed to reveal their actual distribution and importance.

REFERENCES

Chibilev, A.A., 2011, Ural: prirodnoye raznoobrazie i evro-aziatskaya granica (The Urals: natural diversity and Euro-Asian borderline). UrO RAN, Yekaterinburg (in Russian).

Shakirov, A.V., 2011, Fiziko-geograficheskoe raionirovanie Urala (Physiographic zoning of the Urals). UrO RAN, Yekaterinburg (in Russian).

Quantitative GSI determination of Singapore's sedimentary rock mass

***Kar Winn[1], and Louis Ngai Yuen Wong[2]**

[1]*Sr. Project Manager, Geomotion (Singapore) P/L, No. 50, #01-09,Ubi Crescent, Singapore 408568*
[2]*Associate Professor, Department of Earth Sciences, The University of Hong Kong, Pokfulam Road, Hong Kong, China*
**Corresponding author: karwinn@yahoo.com.sg*

The GSI chart, which was developed in 1992, is a mostly qualitative engineering geological assessment of the blockiness of the rock mass and the surface conditions of discontinuities. Though the system works well for geologists or engineering geologists, some engineers tend to be uncomfortable with it because it does not contain parameters that can be measured quantitatively. Hence GSI system has been modified since 1999 to provide quantitative assessment of above two fundamental parameters (blockiness of rock mass and surface conditions of discontinuities). In this paper, GSI for sedimentary rock mass in Singapore determined by two different approaches are presented.

(a) Quantified GSI in terms of RQD and joint condition (Hoek. et al., 2013): In their quantification chart, discontinuity surface condition was scaled with $JCond_{89}$ rating defined by Bieniawski (1989) and the blockiness was scaled with Rock Quality Designation (RQD). The relationship with GSI is as follow:

$$GSI = 1.5\ JCond_{89} + RQD/2 \quad (1)$$

Quantitative GSI assessment was performed on 420 tunnel faces of sedimentary rock which were excavated for an underground storage cavern project as per Eq. 1. The authors proposed the following relationship by replacing RQD/2 by RQD/3 since RQD/2 will lead to much higher GSI values, which do not match the field measurements using Hoek's 1992 GSI chart;

$$GSI = 1.5\ JCond_{89} + RQD/3 \quad (2)$$

The calculated GSI values are between 45 and 55 in majority.

(b) Quantified GSI in terms of block volume (V_b) and joint condition factor J_c (Cai et al., 2004): The block volume is calculated by the product of spacing (s_1, s_2, s_3) among the discontinuity sets as follows;

$$V_b = s_1\ s_2\ s_3 \quad (3)$$

The joint surface condition (J_c) is defined by the waviness (J_w), smoothness (J_s) and infilling condition (J_A) as follows;

$$J_c = J_w\ J_s / J_A \quad (4)$$

The same 420 excavated tunnel faces were again assessed to determine V_b and J_c. The quantified GSI value corresponds to the intersection of V_b and J_c after being plotted. The majority of GSI is between 40 and 55. The quantitative GSI values of Singapore sedimentary rock mass, which were determined by two different approaches are approximately in the same range.

REFERENCES

Bieniawski, Z.T., 1989, Engineering rock mass classification. New York, Wiley Interscience.

Cai, M., Kaiser, P.K., Uno, H., Tasaka, Y. and Minami, M., 2004, Estimation of rock mass deformation modulus and strength of jointed rock masses using GSI system, Int. J. of Rock Mech. Min. Sci. v. 41(1), pp. 3–49.

Hoek, E., Carter, T.G., and Diederichs, M. S., 2013, Quantification of the geological strength index chart, 47th US Rock Mechanics, Geomechanics Symposium, American Rock Mechanics Association, (ARMA), 13–672.

Spatial variability of shallow groundwater level in the northern Kathmandu Valley

***Manish Shrestha, and Naresh Kazi Tamrakar**

Central Department of Geology, Tribhuvan University, Kirtipur, Kathmandu, Nepal
**Corresponding author: angerousmanish@gmail.com*

Water is incompressible substance and is present in the pore space of the geological materials. Presence of small amount of water in geological material modifies the behavior of geological material under stresses. Determination of engineering behavior of the geological material is almost impossible skipping the role of water. The objective of this study was to map and evaluate shallow groundwater level of the northern Kathmandu Valley covering main rivers such as the Bagmati River, Bishnumati River, Dhobi Khola and the Manahara Khola. These rivers flow from the North to the South across the sand rich sediment zone. Static groundwater levels of 239 wells were measured from different locations of the study area in April/March 2017 (Dry Season) and in August 2017 (Wet Season).

Shallow groundwater level was measured from soil surface to water level using well water depth logger (Qin and Li, 1998). The result showed that groundwater level ranged from 0.6 m to 12.5 m in dry season (Fig. 1) and 0.1 m to 13 m in wet season (Fig. 2). The groundwater level increased by average of 48.72% (n = 239) as compared to that in dry season. Increase in the groundwater level suggests recharge of groundwater in wet season of the study area. The flow pattern of groundwater levels from the study shows flow of shallow groundwater towards the major rivers of that particular river watershed. As a consequence, seepage flow and piping erosion is likely along the riverbank slopes. Increase in recharge of groundwater during wet season exhibits that the northern region of the Kathmandu Valley is potential for groundwater recharge and can be used to manage water for the dry period.

REFERENCES

Qin, Y.D., and Li, B.G., 1998, Estimating of groundwater level distribution by disjunctive kriging. Journal of Hydrualic Engineering, v. 8, pp 28–33.

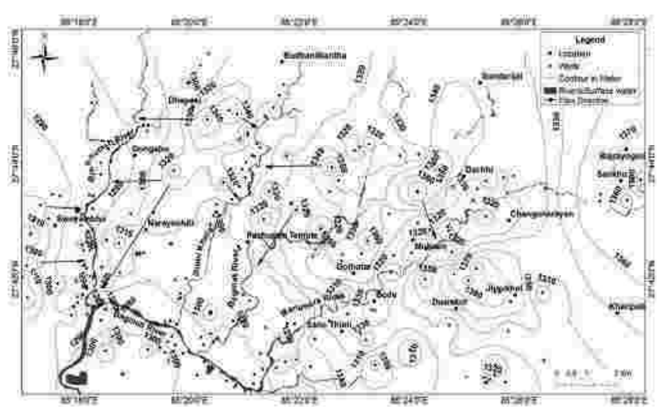


Fig. 1, Water table map of study area of dry season from AMSL

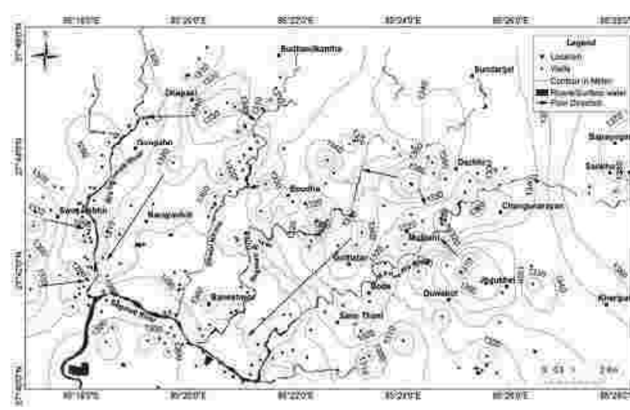


Fig. 2, Water table map of study area of wet season from AMSL

Predictions of saturation process on partially desaturated soil

***Narayan Prasad Marasini[1], and Mitsu Okamura[2]**

[1]National Society for Earthquake Technology-Nepal (NSET)
[2]Graduate School of Science and Engineering, Ehime University, Japan
**Corresponding author: narayanmarasini@gmail.com*

Desaturation by air injection is an innovative countermeasure technique especially for the existing structure founded on liquefiable soil. The reliability of this technique is depends on the sustainability of the injected air in the soil pore. Previous study qualitatively revealed that the lowered degree of saturation by artificially injected air will sustained for a decades or longer. But still there is no proper prediction method that has been developed to foresee the change of degree of saturation with time. To evaluate the change in degree of saturation (which ensures the longevity of injected air) at different seepage flow pressure on partially saturated sand, experiments were conducted in the laboratory (Kasatani and Okamura, 2014). In this study laboratory experiments were numerically simulated with considering advection and the molecular diffusion process of mass transfer by using the multiphase flow simulation model (TOUGH2) based on the finite difference method (FDM).

Air erosion in unsaturated soil at occluded air phase is due to water flow when there is water head difference, and is due to diffusion when there is concentration difference of dissolved air (Fredlund and Rahardjo, 1993). Both the diffusion and advection process of mass transfer has been considered to evaluate the change in degree of saturation by the equation of state 3 (EOS3, air and water flow) under TOUGH2 (Pruess et al., 1999) simulator using PetraSim5 interface model.

In this study, numerical simulation was performed to validate the experiment test to predict the changes in degree of saturation at continue seepage flow in different hydraulic head considering the advection and diffusion process of mass transfer. Results were quite comparable with the test results for all the three cases of laboratory experiment. This study indicates, simulator may be capable of predicting the saturation process after the degree of saturation lowered by air injection technique under arbitrary conditions, and be applicable to field problems to predict the longevity of artificially injected air as flow characteristics are identified.

REFERENCES

Fredlund, D.G. and Rahardjo, H., 1993, "Soil Mechanics for Unsaturated Soils", John Wiley, New York.

Kasatani, R. and Okamura, M., 2014, Experimental analysis on change in degree of saturation in unsaturated sand under different seepage pressure, 49th National conference on geotechnical engineering, Kyusu, Japan.

Pruess, K., Oldenburg, C., and Moridis, G., 1999, TOUGH2 User's Guide Version 2.0, Rep. LBNL-43134, Berkeley, CA, 197p.

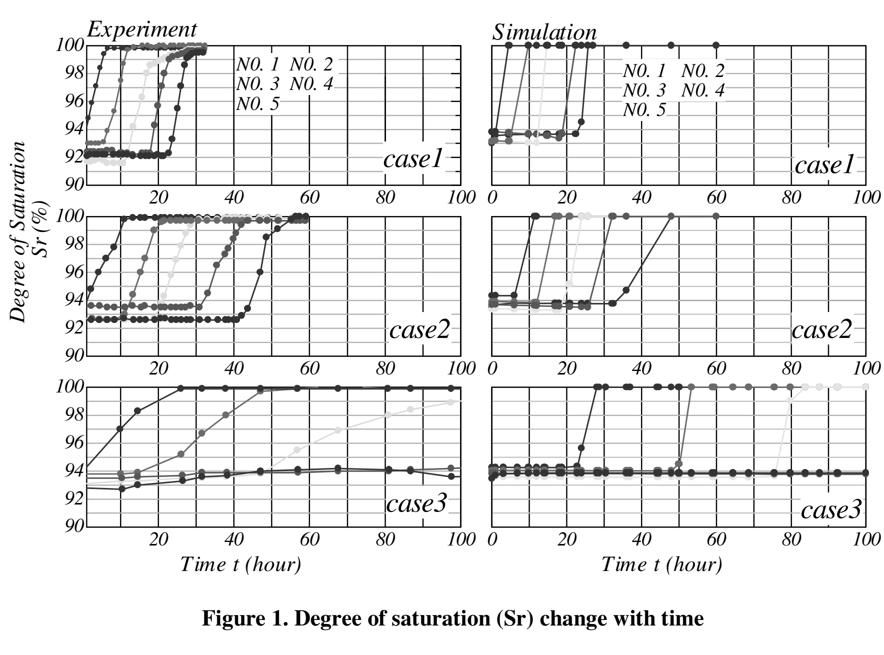


Figure 1. Degree of saturation (Sr) change with time

Geological core drilling on the foothills of the Himalayas: issues, challenges and measures taken while drilling through the gravel/boulder layers

***Om Prasad Dhakal[1], Manita Timilsina[2], and Ranjan Kumar Dahal[3]**

[1]*Geotech Solutions International Pvt. Ltd, Kalika Marg, Lalitpur, Nepal*
[2]*Geotech Solutions International Pvt. Ltd. Kalika Marg, Lalitpur, Nepal*
[3]*Central Department of Geology, Tribhuvan University, Kirtipur, Kathmandu, Nepal*
**Corresponding author: omdhakal74@gmail.com*

Drilling works in Himalayan terrains is always a challenging work to carry out, especially when its core drilling and the job is to bring out core samples which should be undisturbed then the process gets more complex. Machine setup and transportation can also be extremely difficult on rugged terrains. Despite, sudden change in the lithology may need extra precautions and experts advise to cope up easily.

The main challenge that we have been facing here is to carry out drilling in the unconsolidated fluvial deposit. Likewise, instability of the wall rock, maximum drilling bit consumption, pipe wear and tear, loss of drilling fluid, sticking of the pipe, slow rate of penetration are also other emerging problems of this setting.

Considering all the above mentioned problems, carrying out the work with normal drilling condition was quite impossible. So, in order to reduce the problem, we applied advanced lubricating chemicals based on polymers which showed superior performance than Bentonite which, is widely used upon drilling operations. We are using these sorts of advanced chemicals as drilling fluid because this helps in increment in the viscosity of drilling fluid as a result it lubricates the bits and pipes, which makes the drilling process much easier. Also, these chemical helps in stabilization of the borehole and recovery of the core sample. The overall penetration rate tends to improve by 15% after the use of the chemicals. Rest of all, these chemicals has this particular function to prevent water loss on porous layers, polymer containing these chemicals seals the pore space on the wall rock and prevents water loss.

Similarly, the drilling bits needs to be sturdy while drilling in this area as, previously ordinary bits did not perform well. Therefore, we took reference from few companies abroad and started using bits with 12 mm crown and standard hardnesss-8 which sustained better. We have been using varieties of bits including tricone bits with tungsten carbide head and diamond impregnated core bits with differentiated waterways. Out of all these, diamond impregnated bits with face discharge worked well with us as we were facing problems with the broken circulation of the drilling fluids. In addition to that, the drilling fluid was helpful to us as we keep circulation of the drilling fluid low at around 20l per minute so that the core sample won't get washed. Yet, the drill cuttings from deep boreholes are brought out by these chemicals because of the high viscosity of the drilling fluid.

Regarding the technical parameters, we drilled the gravel layers with a rpm of 144 (gear 1), whereas, the fines was drilled with a rpm of 256 (gear 2). Our efforts on improvisation of our drilling techniques had paid us off. There was a substantial increment in the penetration rate from 50 cm per hour to 70 cm per hour upon well sorted boulder layers; likewise, from 85 cm per hour to 95 cm per hour in case of well sorted sand layers within the same parameters. In addition to that broken water circulation, pipe sticking, continuous bit wear had also been minimized.

Formation process of Shigenobu Basin and the mechanism of groundwater flow

***Tomoaki Kayaki[1], and Seisuke Miyazaki[2]**

[1]*Suimon LLC, Hiroshima, Japan*
[2]*Kyushu geological consultant Co Ltd, Fukuoka, Japan*
**Corresponding author: kayaki@suimon-llp.jp*

The Shigenobu fault which is one of the Median Tectonic Line active fault system (Ikeda et al., 2005) is located on the south of Dogo-plain in western Shikoku, Japan. The Shigenobu Basin was formed as pull-apart basin on the south of the Shigenobu fault (Ikeda et al., 2003). The area of the Shigenobu Basin is about10 km in the east-west and 2-3 km in the north-south direction between two confluences of the River Shigenobu-gawa and two tributaries: the River Omote-gawa and the River Tobe-gawa. It is estimated by seismic reflection survey that the basin is filled by thick gravelly sediment which has approximate 600 m thickness (Ikeda et al., 2003). Additionally, the result of the observation of drilling core shows that the basin is mainly composed of fluvial gravel, not of lacustrine sediments like thick silt or clay layer.

The River Shigenobu-gawa flows westward in the middle of the Shigenobu Basin and shows"lost streams" in the drought season. These"lost streams"occur at the upstream of two confluences of the R. Shigenobu-gawa and tributaries of the R. Omote-gawa and the R. Tobe-gawa. Meanwhile, many springs appear on the lower region of "lost streams". The mechanism of springs near the confluence of the R. Shigenobu-gawa and the cR. Omote-gawa can be understood easily, because these springs are groundwater gushing out at the tail of the alluvial fan formed by the R. Shigenobu-gawa. But the mechanism of springs near confluence of the R. Shigenobu-gawa and the R. Tobe-gawa cannot be understood without consideration of formation process of the Shigenobu Basin.

On the right side of the R. Shigenobu-gawa, the valley shaped groundwater table is confirmed parallel to the River (Ichimaru et al., 2008; Miyazaki, et al., 2008). This groundwater flow path corresponds to the belt-shaped low gravity anomaly region at south side of the Shigenobu fault (Ikeda et al., 2003). This means that Shigenobu Basin is formed by the repeated subsidence and aggradation cycles with the continuous movement of active fault system like the Shigenobu fault. Furthermore, it is likely that the Shigenobu Basin is highly productive groundwater reservoir because of its hydrogeological structure which composes of high permeability fluvial gravel filled in the basin and low permeability basement of the Cretaceous Izumi group.

Though the gradient of groundwater table is high until the confluence of the R. Shigenobu-gawa and the R. Tobe-gawa, it turns to extremely low at downstream of its confluence. Moreover because the bottom of the Shigenobu Basin becomes shallow at its confluence, the groundwater flow direction in the basin changes to upward. In other words, the Shigenobu Basin acts as natural underground dam. With this kind of perspective, the groundwater is charged from the river and it flows in a shallow layer of the basin rapidly, after that, its flow direction changes to upward near the confluence of the R. Shigenobu-gawa and the R. Tobe-gawa. Finally, it gushes out to the ground as plenty of springs. Therefore, we conclude that hydrogeological phenomena like"lost streams, " unevenly distributed springs " and " the change of groundwater flow direction"are caused by formation process of the Shigenobu Basin connecting with fault activity like the Shigenobu fault.

REFERENCES

Ikeda, M., Ohno, Y., Hasegawa, S., and Okada, A., 2005, Subsurface Structure and Paleoseismology of the Kominato Fault and the Hongu Fault of the Median Tectonic Line Active Fault System in Northwestern Shikoku, Southwestern Japan, Zisin (Journal of the Seismological Society of Japan. 2nd ser.), v. 57, no.4, 419–439.

Ikeda, M., Ohno, I., Ohno, Y., and Okada, A. 2003, Subsurface Structure and Fault Segmentation along the Median Tectonic Line Active Fault System, Northwestern Shikoku, Japan, Zisin (Journal of the Seismological Society of Japan. 2nd ser.), v. 56, no.2, pp. 141–155

Ichimaru, H., Kayaki, T., Osamu, O., Hijii, T., Saitou, M., and Yanagida, M., 2008, Groundwater Flow system in Shigenobu-gawa Alluvial Fun, Hydro-environments of Alluvial Fans in Japan, Research group on Hydro-environment around alluvial Funs, pp. 283-294.

Miyazaki, S., Hasegawa, S., Kayaki, T., and Watanabe, O., 2008, Hydrogeology of the Shigenobu-gawa Alluvial Fan, Ehime Pref., Shikoku, Japan, Hydro-environments of Alluvial Fans in Japan, Research group on Hydro-environment around alluvial Funs, pp. 275–282.

Application of stable isotope for determination of groundwater origin at Karaha-Telaga Bodas, Garut, West Java

***Wiji Astuti[1], Robbyanto[2], and Rizky Hartawan[2]**

[1]*Graduate Institute of Applied Geology, National Central University, Taoyuan, Taiwan*
[2]*Department Mining Engineering, Bandung Institute of Technology, Bandung, Indonesia*
**Corresponding author: wijias95@gmail.com*

The Karaha-Telaga Bodas is a partially vapor-dominated geothermal system located on the flank of the Galunggung Volcano approximately 15 km east of Garut in West Java. (Moore, 2012). We have collected samples from springs and wells to determine groundwater origin and flow direction of the Karaha-Telaga Bodas area using stable isotope tracer, i.e. tritium (hydrogen-3), deuterium (hydrogen-2) and oxygen-18. The values of tritium (hydrogen-3), deuterium (hydrogen-2) and oxygen-18 were obtained from laboratory analysis. Groundwater genesis has been determined by analyzing deuterium (Hydrogen-2) and Oxygen-18. Determination of flow direction of groundwater has been conducted by analysing tritium (Hydrogen-3). The result showed that deuterium (hydrogen-2) and oxygen-18 composition of each sample was (-46.1±2.7) up to (-40.0±1.9) and (-6.33±0.21) up to (-3.93±0.46) above of meteoric water line, respectively. The highest (Hydrogen-3) composition was in the location of MAP-KB-01 (3.11 ± 0.09) and the lowest in the location MAP-TB-03 (1.79 ± 0.03). Based on the result of groundwater of the Karaha Telaga-Bodas originally from meteoric water, groundwater flow comes from the southern area to the northern area of the Karaha Telaga Bodas.

REFERENCES

Moore, J.N., 2012, The Evolution of Partially Vapor-Dominated Geothermal System at Karaha Telaga-Bodas, Indonesia: Insight from Mineral Distribution and Fluid Inclusion Measurement, New Zaeland geothermal workshop 2012 Proceedings.

System reliability analysis of a circular tunnel face stability considering a two-layered ground

***Peng Zeng[1], Tianbin Li[1], Salvador Senent[2], and Rafael Jimenez[2]**

[1]State Key Laboratory of Geohazard Prevention and Geoenvironment Protection, Chengdu University of Technology, Chengdu, China.
[2]Department of Ground Engineering, Technical University of Madrid, Madrid, Spain.
**Corresponding author: zengpeng1987@hotmail.com*

The stability of the tunnel face is always of concern in tunnel design and construction, as the collapse of the tunnel face may endanger the construction facilities and lives, and also might induce the ground collapse and settlement. A circular tunnel driven by a pressurized shield in a two-layered ground with a softer-top and stronger-bottom was taken into account in this study (Senent and Jimenez, 2015), and the stochastic response surface method (SRSM) using linearly independent collocation method (Jiang et al., 2014) was employed to evaluate the system probability of failure of the tunnel face. Cohesion and friction angle of soil were treated as correlated random variables with lognormal distributions. Two limit state functions (LSFs) were constructed to consider the global and partial collapses of the tunnel face, respectively. The Monte Carlo simulation (MCS) was applied directly on the response surfaces built up by the SRSM to assess the system probability of face collapse. Sensitivity analysis was conducted to find out the influences of interlayer position and of the support pressure in the system probability of face collapse. Results indicate that the interlayer position will significantly affect the stability of tunnel face, and that the system probability of failure decreases with the increasing support pressure.

REFERENCES

Jiang, S.H., Li, D.Q., Zhou, C.B., and Zhang, L.M., 2014, Capabilities of stochastic response surface method and response surface method in reliability analysis. Struct. Eng. Mech., v. 49, pp. 111–128.

Senent, S. and Jimenez, R., 2015, A tunnel face failure mechanism for layered ground, considering the possibility of partial collapse. Tunnelling and Underground Space Technology, v. 47, pp. 182–192, doi: http://dx.doi.org/10.1016/j.tust.2014.12.014.

Optimum support estimation in proposed middle Trishuli Ganga Hydroelectric Project, Rasuwa and Nuwakot

***Ujjwal Acharya, Khagendra Dahal, Kamala Kant Acharya, Sunil Kumar Dwivedi, and Subesh Ghimire**

Central Department of Geology, Tribhuvan University, Kirtipur, Kathmandu, Nepal
**Corresponding auther: theujjwal1@gmail.com*

The proposed Middle Trishuli Ganga Hydroelectric Project (MTGHP) lies between 3097400 N to 3094400N and longitude 0616800E to 0616200E in Nuwakot and Rasuwa districts of central Nepal. Geologically, the area lies on Central Nepal, Lesser Himalaya, and the rock type comprises predominantly metasandstone with partings and thin bands of phyllite, which is equivalent to rock type of the Kuncha Formation. The determination of optimum support for the construction of tunnel is directly related to the cost of the project; so some modeling techniques is necessary for maximum performance of the tunnel with minimum support.

The study focuses on the finite element analysis using Phase^2 8.0 on the four chainage: 0+230m, 0+515m, 1+380m and 2+410m of the Headrace Tunnel (HRT) to determine the optimum bolt length and pattern for proposed MTGHP. The material properties and detailed topographic map used in this analysis were provided by Gorkha Hydro and Engineering Pvt. Ltd, and other required parameters were obtained using RocData software. The chosen chainage has overburden of 110m, 65m, 244m and 74 m, and projected RMR is 58, 58, 68 and 73 respectively. The initial stresses were obtained from simulation on the valley slope model, and segmented type tunnel of 4m diameter. Six different bolt lengths and 3 different bolt spacing with altogether 18 combinations were simulated and minimum yielded elements amongst these combinations were designated as optimum support. For 0+230m, 0+515m, 1+380m and 2+410 m chainage, the optimum bolt length and spacing were 1.5m × 1m, 2m × 1m, 3m × 1m and 1m × 1m respectively. Liner/Shotcrete after bolting further aids stability of the tunnel.

It is concluded that using variable bolt length according to the requirement of the material helps reducing significant cost of the project, and over supporting would not assist on further stability of tunnels.

Development of technology for long-term monitoring and automatic data acquisition system

***Akira Shidai[1], Kenzo Kiho[1], Yasuji Saito[2], and Tomohiro Kawakami[3]**

[1]Central Research Institute of Electric Power Industry (CRIEPI), Chiba, Japan
[2]Tokyo Electric Power Services Co., Ltd. (TEPSCO), Tokyo, Japan
[3]Toyo Electric Co., Aichi, Japan
**Corresponding author: shidai@criepi.denken.or.jp*

It is very important to understand the baseline of various environmental characteristics by monitoring in the borehole to observe and estimate the long-term transition and behaviour of natural phenomena. High-level radioactive waste (HLW) is planned to be geologically disposed in Japan. Underground facilities and final repository of HLW might affect geological, environmental and radiological conditions. Therefore, it is important to obtain the initial states of pore water pressure and water chemistry through long-term monitoring in the boreholes before construction of these facilities. CRIEPI has been conducting a project for developing the directional drilling and measurement/logging technologies to survey hydro-geological condition during the investigation for site selection. A 1000 m length borehole was drilled by directional drilling technology in order to verify the drilling technology in Hokkaido. Long-term monitoring technology to clarify pore water pressure and water chemistry in the drilled borehole was also developed. Three measurement sections in the borehole were set on a hanging wall side of a main fault in 2013 and measurement of pore water pressure was started in 2014.

The investigation for site selection will be achieved in wide areas away from human living environment where power supply and/or communication networks are not available. An automatic data acquisition system for long-term monitoring under such circumstances was developed. The system is based on the plant data wireless automatic data acquisition section and monitoring system (open ATOMS), which has various reliable records at the nuclear power plants for radiation monitoring.

The configuration diagram of the automatic data acquisition system performs data communication and measurement of long-term monitoring of pore water pressure, surrounding environment data and measurement equipment information using less electricity under the harsh conditions. The power is supplied from solar and/or wind power generation. Measurement data are collected in a network computer by wireless Zigbee network. Data communication is secured through a satellite line or 3G/4G line according to the local communication network service. Real-time consecutive monitoring is possible by remote control at the time of the event outbreak such as a big earthquake. Simultaneous monitoring is also possible by creating local wireless network for each survey point.

The demonstration of the system was conducted at the northernmost area of Hokkaido. The environment of the demonstration site is very severe and the temperature will be close to minus 30 degree Celsius in winter. The system had been operated for one and a half year while adjusting the system equipment and it was confirmed that the system has enough reliability for the actual operation. The system could be applied to the investigation and monitoring of the natural disaster such as landslides and other geohazards.

Landslide Mapping Using GIS and Related New Technology

***Hiromisu Yamagishi, Kazuo Shimura, and Kenichi Saito**

Shin Engineering Consultant Co. Ltd., Sapporo, Japan
**Corresponding author: hiromitsuyamagishi88@gmail.com*

Landslide mapping is primarily begun from inventory mapping for successively susceptibility mapping, hazard mapping and risk mapping (CRNLHMS, 2004). Inventory mapping has been done effectively and traditionally, using stereo-paired analogue air photos. However, such stereo-paired sets are not necessarily obtained in any areas or countries. Recently, 1) satellite image such as Google Earth, covering all of the world, 2) DEM (digital elevation model; such as 30 m-DEM at least), and 3) image system such as RRIM, CBZ and CSS system etc., are found useful tools for landslide inventory. This paper describes how to use them for it.

1) Google Earth is the best and free satellite image for inventorying landslides (Moncada and Yamagishi, 2017; Fig. 1)

2) The 30 m-DEM can be downloaded freely from the website https://gdex.cr.usgs.gov/gdex and then the raster data and contour line maps can be obtained by GIS software (ArcGIS and Q-GIS, etc). On the contour line maps, abnormal topography suggesting landslides is selected and polygons of scarps and bodies were made. Finally, combination of satellite images and DEM data inventory landslides.

3) CBZ (Chibouzu) is one of a system made up from the factors of DEM (slope, elevation and rate elevation). Observation of CBZ reveals large-scale landslide topography (Fig. 2), although it of course depends on the resolution of DEM.

4) In Japan, the distributions of heavy-rainfall induced shallow landslides at six locations were inventoried by the aerial photographs just after the events, and then analyses were done for the relationships between the landslide numbers/areas and slope gradients at each area. Results showed that shallow landslides are concentrated on slopes with gradients between 25° and 30°, regardless of the difference in bedrock geology (Yamagishi et al., 2013). It suggests that the occurrence of shallow landslides depend on slope gradient rather than bedrock geology; namely the materials of these landslides are weathered soils or ash-falls

REFERENCES

Committee on the Review of the National Landslide Hazards Mitigation Strategy (CRNLHMS), 2004, Partnership for reducing landslide risk. The National Academic Press, Washington DC, 123p.

Moncada, R, and Yamagishi, H., 2017, Report of Enhancing Natural Hazards Resilience in South America (ENHANS) Landslide training activity at Santiago de Chile: May 8-12, 2017, UNESCO, 37p.

Yamagishi, H., Doshida, S. and Pimiento E., 2013, GIS analysis of heavy-rainfall induced shallow landslides in Japan. *In* Landslide Science and Practice. v. 1. Landslide inventory and susceptibility and hazard zoning, Springer Verlag, pp. 601–607.

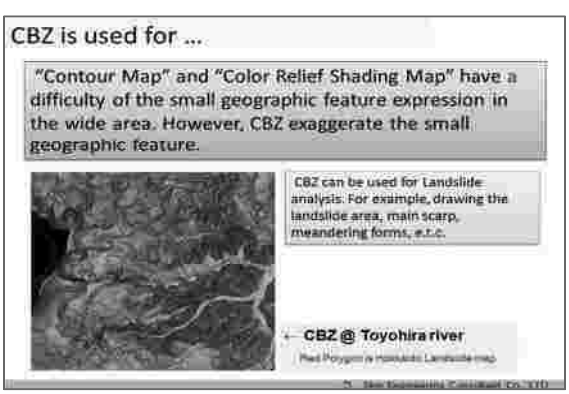


Fig. 1, Landslides inventoried by Google Earth

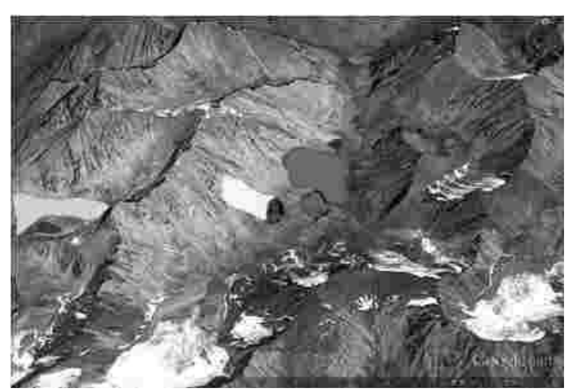


Fig. 2, Landslide maps on Chibouzu (CBZ)

Hydrogeochemical criterion as applied for mapping hydrogeological windows

***Irina Galitskaya, Irina Kostikova, Irina Pozdnyakova, and Leonid Toms**

Sergeev Institute of Environmental Geoscience Russian Academy of Science (IEG RAS), Moscow, Russia
**Corresponding author: galgeoenv@mail.ru*

Being the largest reserve of drinkable water for human population, groundwater has always been of major importance to human civilization. The presence of oil products, heavy metals and the other contaminants in groundwater has become one of the major environmental concerns in densely populated and highly industrialized countries. Freshwater of confined aquifers in the upper hydrodynamic zone is of utmost importance, because it appears to be a reliable water source due to its considerable operational reserve, high quality, and natural protection from contamination. However in the zones of elevated permeability of aquitards covering the confined aquifer (the so-called “hydrogeological windows”), upon the downward infiltration, the contaminants from subsurface groundwater aquifers may reach the confined aquifers and deteriorate the water quality.

In this study we focused on ascertaining the possibility of hydrogeochemical criterion using for determining the location of hydrogeological windows on the territory of Moscow. This criterion is based on the following assumption: since the confined Podolsko-Myachkovskii aquifer in Carboniferous deposits (potential source of drinking water) in such areas is least protected from contamination, the elevated concentrations of technogenic contaminants can be used as a hydrogeochemical criterion of hydrogeological windows location. There is a direct interconnection of “above-Jurassic” and Podolsko-Myachkovskii aquifers and contaminants can enter from overlying “above-Jurassic” aquifer.

Study of hydrogeological window’s influence on Podolsko-Myachkovskii aquifer contamination consisted of (i) analyses of groundwater chemical composition in “above-Jurassic” and Podolsko-Myachkovskii aquifers; (ii) the choice of contamination indicators; (iii) the construction of schematic maps of the contamination indicators’ spatial distribution.

The waters of the "above-Jurassic" aquifer contain elevated concentrations of contaminants (chloride, nitrate, oil products, ammonium, and phenols) associated with the infiltration of contaminated wastewater and also contaminants due mainly to the natural factor, namely the interaction in the system "water-rock" (iron, manganese). The contamination indicators can serve for the components of technogenic origin. The best indicator of contamination is chloride ion, not adsorbed by the rocks and unaffected by physicochemical transformations. In addition, temporary changes in chloride concentrations within the study area is quite stable.

The research results showed that significantly elevated concentrations of indicators were contained in the Podolsko-Myachkovskii aquifer just at the sites of "hydrogeological windows" which were allocated according to geological structure, hydrogeological and tectonic conditions. The most clearl influence of hydrogeological windows is traced by the distribution in groundwater of mineralization and chloride concentrations (Fig. 1). Recommendations for further research were outlined according to the obtained results.

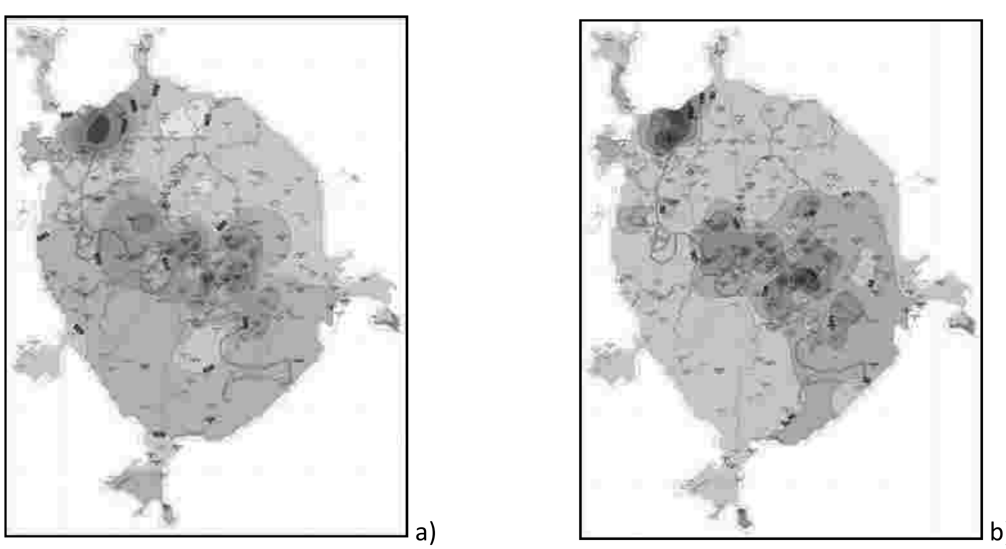


Fig. 1, Schemes of the mineralization (a) and chlorides (b) distribution in the Podolsko-Myachkovskii aquifer

An attempt to predict ground motion using scenario earthquakes

Sudhir Rajaure

Department of Mines and Geology, Lainchaur, Kathmandu, Nepal
E-mail: srajaure@gmail.com

Earthquake catalog has been prepared for Nepal and the adjoining region collecting catalogs from various sources. The Gorkha Earthquake rupture area and its southern part are used as two scenario earthquakes. An attempt has been made to predict peak (horizontal) ground acceleration (PGA) using scenario earthquakes in the Central Nepal. The seismicity parameters derived from the catalog are used to simulate PGA following probabilistic technique of seismic hazard analysis. The preliminary result, using the 2015 Gorkha Earthquake Rupture Area as a source, shows that the PGAs for 100-, 200- and 500-year return periods are 120, 210 and 375 gals respectively at the middle of Kathmandu Valley. Similarly, using the southern part of the 2015 Gorkha Earthquake rupture area (which did not rupture during the earthquake), the PGAs at the middle of Kathmandu are 55, 83 and 115 gals for 100-, 200- and 500-year return periods.

Credible zone analysis for SAR data in valley area

Jiaxuan Huang, *Mowen Xie, and Yan Du

Department of civil and resources engineering, University of Science and Technology Beijing, Beijing, China
**Corresponding author: 499784930@qq.com*

The aim of this paper is to analyse the geometric distortion effects in synthetic aperture radar (SAR) data of valley area. In particular, this paper derives two coefficients to express the quality of SAR data. The results show that the backscattering coefficients (BC) and the coherence coefficients (CC) in valley area have close relationship with local incidence angle (LIA). According to this relationship, the credible zone of SAR data was extracted in valley area. This method is then tested on Wudongde area.

Evaluation of sediment dynamics of mountain stream based on variation of sediment deposition

***Ryunosuke Nakanishi , Yuki Okajima, Akira Baba, Yasuhiro Mitani, and Hiro Ikemi**

Graduate School of Engineering, Kyushu University, Japan
**Corresponding author: nakanishi@doc.kyushu-u.ac.jp*

Sediment is transported in the river in case of heavy rain. The amount of sediment transportation is different depending on the characteristics of the basin. The bias of sediment transportation is a negative effect on surrounding environment, for example, ecosystem change and increasing flood risk. Comprehensive sediment management is necessary to solve these sediment problems. Sediment management is a serious problem, especially in the river in which artificial structure is built.

The study area is located on two tributaries of the Mimikawa Basin in Miyazaki Prefecture, Japan. The characteristics of the basin are steep terrain, and there are seven hydroelectric dams in the basin. The catchment area is 884.1 km^2. As shown in Fig. 1, the Shimanto Supergroup mainly composes surface geology of the area, and it distributes from the northeast to the southwest, where strata repeatedly exist because of several strike fault. The Kawauchi River mainly consists of sandstone, whereas the Masutani River mainly consists of mudstone as surface geology.

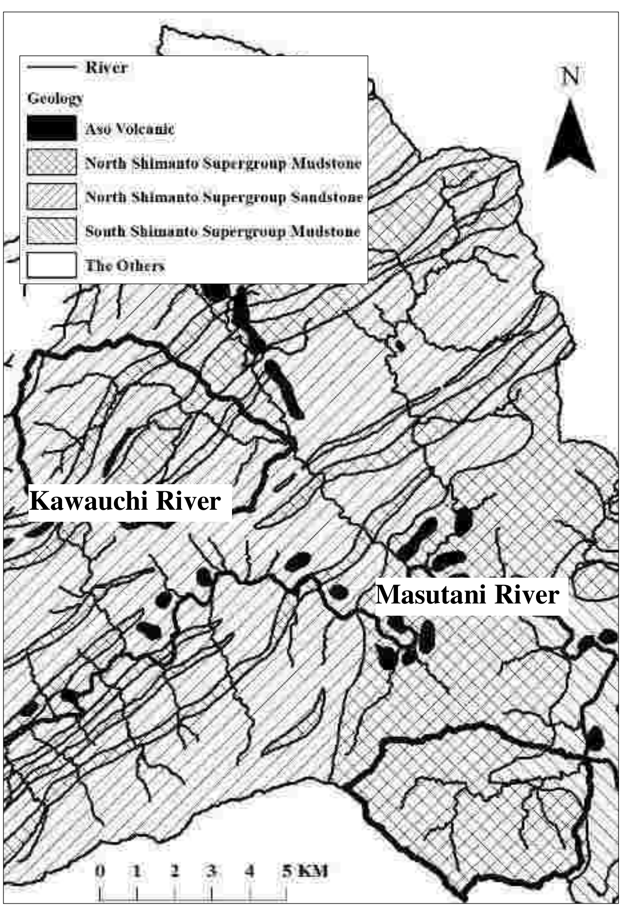


Fig. 1, Geological map of the Mimikawa Basin

Generally, the amount of sediment from the mountains is estimated proportional to the catchment area (Ashida, et al., 1974). In the dam management of Japan, the catchment area is often used as an indicator of the sediment amount. However, previous surveys signified that mudstone plays a vital role in sediment transport compared with sandstone (Nakanishi, et al., 2015). It is difficult to measure accurate sediment amount in flooding because sediment transport mechanism is complex. On the other hand, change in sediment deposition before and after flooding is characteristic, and is an indicator of moving sediment.

In this study, sediment dynamics has been evaluated in two different types of geological regions. Sediment dynamics include the amount of moving sediment, the timing of sediment transport, and the location of sediment production. Firstly, a part of sediment deposition in the river was photographed by UAV. The 3D model was constructed based on pictures by SFM. Seasonal variation of sediment deposition was quantitatively evaluated from the 3D model of the river. The amount of moving sediment from each tributary was calculated by one-dimensional analysis based on the survey results. Quantitative variation of sediment deposition was used as correct data to calculate accurate sediment amount from tributaries. The analysis period was from July to November including multiple floods. As a result of calculation, the amount of moving sediment from the Masutani River was about six times that from the Kawauchi River, and sediment transport was more active in a basin containing more mudstone. In addition, the result was close to the actual phenomenon in case that sediment supply was nothing after the large flood. Therefore, it was considered that the ratio sediment transport in the river to sediment production changed depending on the size of the flood.

REFERENCES

Ashida, K., Okumura, T., 1974, Study on sedimentation in reservoirs, Disaster Prevention Research Institute Annuals, v. 17B, pp. 555–570.

Nakanishi, R., Mitani, Y., Ikemi, H., Hendra, P., 2015, A study on the relevance of geology and sediment discharge in mountain watershed of Shimanto accretionary complex, Proceedings of Asian Regional Conference of IAEG, CDROM.

Construction of a geological information CIM management system and application to construction sites

***Shinji Utsuki, Masashi Nakaya, Ryosuke Tsuruta, and Kazuhiro Onuma**

[1] *Hazama Ando Corporation, Tokyo, Japan*
**Corresponding author: utsuki.shinji@ad-hzm.co.jp*

In bedrock construction projects such as dams and tunnels, it is important to have a detailed grasp of the geological situation at the project site and to perform planning and construction appropriate to the situation. To that end, geological surveys and geophysical surveys are performed at the investigation and design stages to evaluate geological distribution and engineering characteristics at the planned site, and dam foundations and tunnel falsework are designed based on the results. However, at the investigative and design stages there tends to be cost limits as well as limits to the precision of the above-described geological investigations and geophysical investigations, making it difficult to obtain a detailed understanding of the geological situation over a wide area at this stage.

To address these issues, actual excavation and tunnel faces are evaluated during construction to confirm details of the geological situation directly, and to evaluate any differences from the expected situation. Depending on the results, it is important that additional engineering measures be considered and construction plans and designs reevaluated accordingly.

Against this background, there have been various investigations of a method called “construction information modeling” (CIM) in recent years (Fig. 1). Specifically, the geological situation as predicted from preliminary surveys is represented as a 3D model, and construction planning performed based on detailed verification of the distribution of ground defects so that appropriate measures can be employed. During construction phases, the results of geological observations of tunnel and excavation faces are added to the 3D model, thereby achieving more sophisticated and efficient construction results and aiding in reevaluations of construction plans and designs according to the situation at hand.

This paper describes various investigations of a CIM management system for tunnel and dam excavation construction sites, including specific system content and cases of application to actual construction projects.

REFERENCES

Japan Federation of Construction Contractors, 2014, CIM application to actual construction sites in Japan, pp. 1–118.

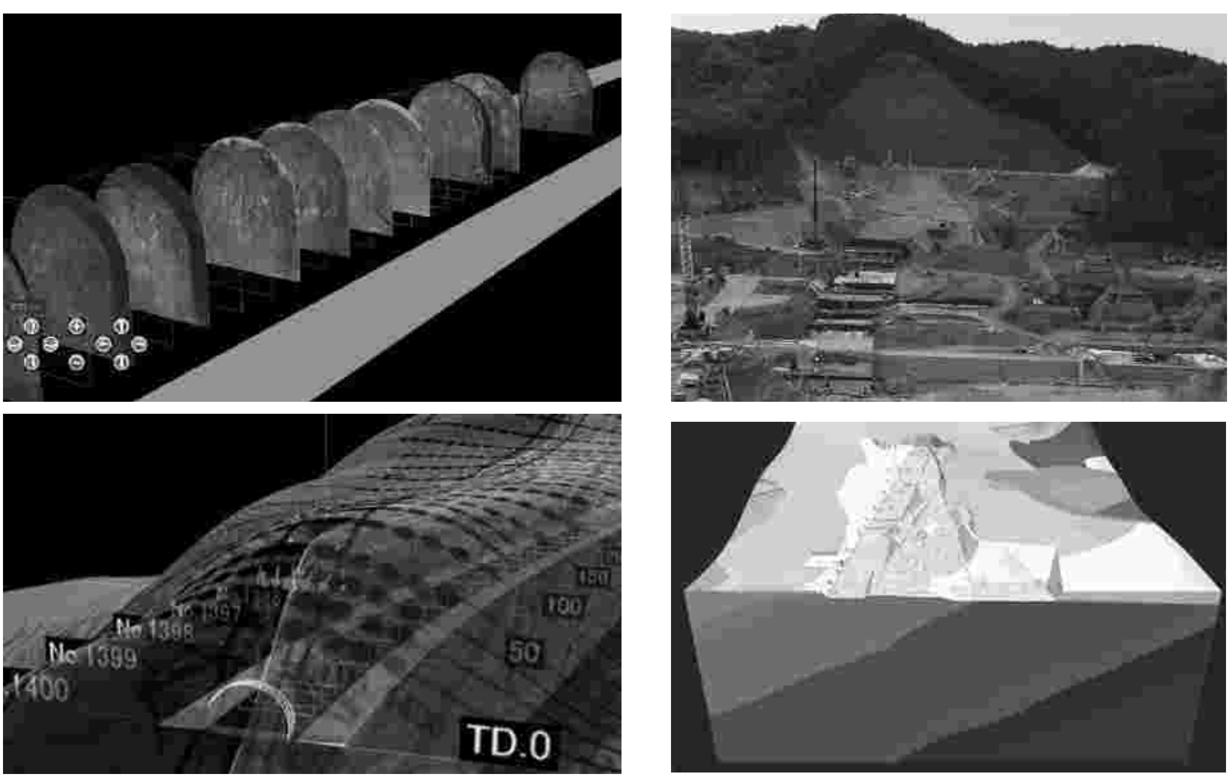


Fig. 1, CIM management system at a tunnel and dam construction site

Comparison of SPAC and CCA methods of analysis to estimate subsurface shear wave velocity structure using microtremor array measurements

***Tara Pokharel[1], Toshiaki Yokoi[2], and Takumi Hayashida[2]**

[1]*Department of Mines and Geology, Lainchaur, Kathmandu, Nepal*
[2]*International Institute of Seismology and Earthquake Engineering (IISEE), Building Research Institute (BRI), Tsukuba, Japan.*
**Corresponding author: tara_geo@yahoo.com*

This study is aimed to conduct the microtremor array exploration for the estimation of shallow shear wave velocity (Vs) structure around the strong motion observation station at Department of Mines and Geology (DMG), Kathmandu, Nepal and to check the performance of the method by comparison of the results given by the following methods of analysis.

The data for analysis were acquired by deploying the three types of arrays; Three point (3p)-array, L-Shaped (L)-array and Hexagonal (Mini)-array in the premises of the DMG. Three sets of three-component accelerometers (McSsis-MT NEO) for 3P-array, 24 geophones for L-array and seven seismometers (L22D) for Mini-array along with data logger (McSeis-SW) were used for the data acquisition. Two microtremor array analysis methods, Spatial Autocorrelation (SPAC) and Centerless Circular Array (CCA) were applied to estimate the subsurface Vs structure.

Vertical component of microtremor records that are supposed to be dominated by Rayleigh waves are used in this study. Using the determined SPAC and CCA coefficients, the dispersion curves of Rayleigh-wave phase velocity were determined. The dispersion curves of 3P-array and L-array that are independently determined are combined together for being inverted Vs structure. The frequency ranges of this combined dispersion curve are from 2 Hz to 15 Hz and are taken as the reference curve to analyze the effectiveness of CCA method. The dispersion curves obtained from the CCA method have the frequency range from about 3.5 Hz to 13 Hz.

The Vs structure inverted from the dispersion curve determined using SPAC method by assuming of three layers, shows Vs about 195 m/s up to 12 m depth from the ground surface, from 12 m to 34 m Vs is 237 m/s and below 34 m depth the velocity seems to increase. Vs structure obtained from CCA method with three radii of array shows the two velocity layers. One is comparatively low velocity surface layer (145 m/s - 184 m/s) up to 7 m depth from the ground surface and the other is little high velocity layer (227 m/s -236 m/s) up to 24 m depth for three array of different radii.

The result of the exploration up to 25 m depth is summarized as a two layered structure. The surface layer has Vs 145 m/s to 195 m/s up to 12 m followed by higher Vs 227 to 237 m/s. The results from both methods are comparable with each other.

The results show that CCA method is more effective than the SPAC method as it explored the same depth even in the smaller radius array in term of the applicability in sites densely built up. We obtained the similar depth from SPAC method with maximum 84.9 m interstation distance and CCA method with 4 m radius only. Especially in the urbanized area such as Kathmandu city, where there is less space for the array of SPAC method, CCA method seems available and more effective.

Application of advanced Japanese practices of 3D scanning and monitoring technologies to national restoration and preservation projects in Kathmandu Valley

Proshchanka Dzianis

KUMONOS Corporation, Osaka, Japan

E-mail: Dennis@kankou.co.jp

Current work demonstrates real-life application of the advanced Japanese practices of monitoring and 3D modelling of historically important structures and socially significant objects. The work is done to facilitate recovery efforts on the earthquake damaged National Heritage sites. The ongoing project is been performed in close cooperation with Department of Archaeology (DoA) and National Reconstruction Authority (NRA) with close support of Himalaya Conservation Group (HCG) and Geotech Solutions International (GSI). It involves instrumental surveying of Tri-Chandra Campus of Tribhuvan University, Kumbeshwar Patan, Degu Taleju in Patan, Bhaktapur Durbar Square, Swayambhu Stupa and some other historical sites. We have been able to create a detailed three-dimensional model of Ghantaghar Clock Tower of Tri-Chandra campus and produced digital detailed information on cracking and other defects which will allow structural engineers to perform the analysis and make necessary decisions on reconstruction activities. The current survey is also realized with financial support of Japanese Government.

Distribution of earthquake triggered landslides by the 2015 Gorkha-Earthquake in the Nepal Himalaya

Kaushal Raj Gnyawali[1], and *Basanta Raj Adhikari[2]

[1]*School of Naval Architecture, Ocean and Civil Engineering, Shanghai Jiao Tong University, China*
[2]*Department of Civil Engineering, Institute of Engineering, Tribhuvan University, Nepal*
**Corresponding author: bradhikari@ioe.edu.np*

The Gorkha Earthquake triggered many co-seismic landslides in the Central Nepal. More than 19000 (>20 m^2) landslides have been identified covering of 61.5 Km^2 of land in about 20000 Km^2 area of investigation by using the Google Earth imagery. Regional localization and angular distribution of the landslides, which are controlled by the rupture directivity is observed. Landslide Area Percentage (LAP) and Landslide Number Percentage (LNP) proxies are used to study in comparison with % area of each parameter classes (seismic, topographic and geologic). Positive correlation with the chosen triggering parameters are observed but there are some significant differences in the parameter values and distributions. This study provided valuable information about the use of space base science for landslide study and this is important in further researches on co-seismic landslide prediction models for mountainous settlements, sediment yield studies and cascading landslide disasters after major earthquakes.

The Study of Energy Released and Strong Ground Motion during the 2015 Gorkha Earthquake using Wavelet Analysis

***Binod Adhikari[1,3], Subodh Dahal[2], Monika Karki[1], Roshan Kumar Mishra[1], and Narayan P. Chapagain[3]**

[1]*Department of Physics, St. Xavier's College, Maitighar, Kathmandu, Nepal*
[2]*Department of Physics, Himalayan College of Geomatic Engineering and Land Resource Management*
[3]*Department of Physics, Patan M. Campus, Tribhuvan University, Patan Gate, Lalitpur. Nepal*
**Corresponding author: binod.adhi@gmail.com*

This work is based on the energy release during the earthquake and the time-frequency characteristics of strong ground motion. The main reason of the study is to estimate energy using the moment magnitudes of the earthquake and make analysis from those data. This is directly related to the study of unpredictable natural phenomena so it is also related to the study of geophysics and the aspect of the threat to human life. In this study, we use the idea of time- frequency characteristic of the seismic wave energy of earthquake based on wavelet transform. Both continuous and discrete wavelet transform have been implemented in this work. Wavelet transform has been used as a powerful signal analysis instrument in the various fields of application like compression, time-frequency analysis, earthquake parameter determination, climate studies etc. This new technique is particularly suitable for non-stationary signal. The main purpose behind the translation of this signal is to expose the characteristics or features unseen within the unusual signal and characterize the original signal more effectively. Here the wavelet transforms has been used to develop software for analyzing noisy and temporary signals and its capacity to represent the signal in both its time and frequency domains. With the current appearance of wavelet-based procedures for stochastic analyses of linear and non-linear structural systems subjected to earthquake ground motion, it has become required that seismic ground motion processes are characterized through statistical functional of wavelets coefficients. It is well recognized that the earthquake ground motion is a non-stationary random process. To characterize a non-stationary random process, it requires immeasurable samples in mathematics sense. In practice, it is impossible. So we adopted certain time of waves here to construct a sample base, which describes an earthquake ground motion in some extent.

Landslides triggered by the Gorkha, Nepal Mw7.8 earthquake of 25 April 2015: A comparison with the 2008 Wenchuan, China Mw7.9 event

***Chong Xu[1], Yingying Tian[1], Lingling Shen[2], Xueqiang Huang[3], Junxue Ma[3], Xi Chen[3], Siyuan Ma[1], and Xiwei Xu[1]**

[1]Key Laboratory of Active Tectonics and Volcano, Institute of Geology, China Earthquake Administration, Beijing, 100029, China
[2]Beijing Meteorological Information Center, Beijing Meteorological Service, Beijing, 100089, China
[3]School of Engineering and Technology, China University of Geosciences (Beijing), Beijing 100083, China
**Corresponding author: xuchong@ies.ac.cn*

The April 25, 2015 Gorkha Mw7.8 earthquake occurred in central Nepal. The present architecture of the belt is dominated by three approximately parallel main thrusts with low dip angles (~10°), i.e. the Main Frontal Thrust (MFT), the Main Boundary Thrust (MBT), and the Main Central Thrust (MCT), from south to north in the order of increasing ages of thrust initiations. The rupture direction of the earthquake is about east and most aftershocks occurred in a rectangle area about140 km in NWW-SEE direction and 50 km in NNE-SSW direction east to the epicenter. The large aftershock of May 12, optical satellite images pre- and post-earthquake, we delineated 47,200 coseismic landslides in an area more than 35,000 km^2 (Fig. 1) 2015 Mw7.3 is located to the east of the epicentral area of the mainshock. Based on visual interpretation of high-resolution.

We also carried out field surveys to map the landslides along two main highways, i.e., Araniko Highway and Pasang Lhamu Highway. We examined the coseismic landslides that blocked or damaged the two highways in Nepal. Results show 35 coseismic landslides damaged the Araniko Highway and the total length of the buried or damaged roads is about 1,415 m. The total volume of the failed landslide mass was about 0.37 Mm^3. We delineated 89 coseismic landslides that damaged the Pasang Lhamu Highway, where the total length of the damaged or buried roads is about 2,842 m. The total volume of the 89 landslides is about 1.47 Mm^3.

The 2008 Wenchuan China earthquake (Mw7.9) has a similar magnitude in comparison to the Gorkha event. However, the two comparable earthquakes produced greatly different coseismic landslides. The Wenchuan earthquake triggered at least 197,481 landslides, distributed in an area about 110,000 Although the landslides triggered by the Gorkha earthquake were affected by multiple factors and the geologic setting of the affected area is rather complex, we consider the low-angle seismogenic fault and associated deformation causing less internal block damage may be the primary factors responsible for the intensity of the coseismic landslides.

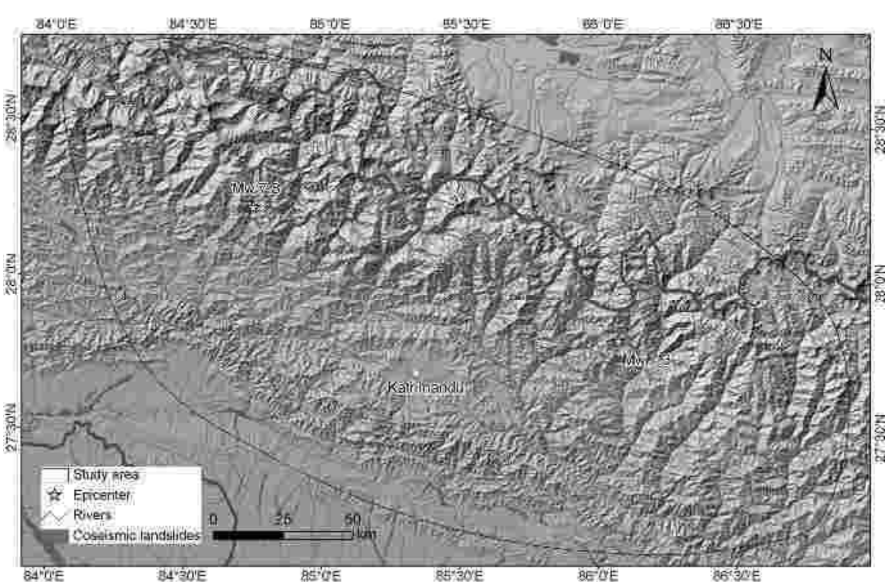


Fig.1, Distribution map of landslides triggered by the Gorkha earthquake

Landsliding distribution relative to the 2015 M_w 7.8 Gorkha Earthquake, Nepal

***Marin Clark[1], Dimitrios. Zekkos[1], Kevin Roback[12], William Medwedeff[1], William Greenwood[1], A. Joshua West[3], Deepak Chamlagain[4], and Bibek Giri[5]**

[1]*University of Michigan, Ann Arbor, MI 48109 USA*
[2]*California Institute of Technology, Pasadena, CA 91101 USA*
[3]*University of Southern California, Los Angeles, CA 90089 USA*
[4]*Department of Geology, Tri-Chandra Multiple Campus,Tribhuvan University, Kathmandu, Nepal*
[5]*Central Department of Geology, Tribhuvan University, Kathmandu, Nepal*
**Corresponding author: marinkc@umich.edu*

The distribution of landsliding during large earthquake events provides an opportunity to assess factors controlling regional landslide hazard in mountainous regions. In April 2015, the M_w7.8 Gorkha earthquake caused 25,000 landslides throughout the steep topography of central Nepal. The east-west extent of lansliding closely follows the extent of fault rupture, with an increase in landslide density eastward. The east-west distribution of landsliding mimics the west to east progression of south-directed thrust motion during the earthquake. Contribution by the May M_w7.2 aftershock near Kodari may have also contributed to greater landsliding in the east, however, preliminary evaluation of satellite imagery suggests that this is not the case. A majority of landslides were concentrated north of the physiographic transition, which separates moderately steep topography of the Lesser Himalaya from the deeply incised and glaciated High Himalayan topography. While PGA estimates produced by the USGS suggest low values within the High Himalaya (<0.25 g), these estimates are largely unconstrained by felt reports and instrumentation in this region. Our analysis of small failures on river terraces suggests that the region experienced much higher accelerations, likely similar to those felt in the Lesser Himalaya.

We also find that landslides were closely associated with the major north-south draining river channels despite similarly steep slopes adjacent to smaller rivers. Landslides also appear to be concentrated along stretches of river with high normalized steepness. Notably, fewer landslides were observed in the alpine regions above 4000 m elevation, within glaciated and formerly glaciated terrain despite the greater abundance of slopes > 40 degrees in this region. Taken together, our results suggest (1) the potential strong ground motion beneath the High Himalaya is sufficient to cause wide spread landsliding in large earthquakes despite the greater depth to the fault plane in this region, (2) the correlation of landslide density with channel metrics (steepness, and drainage area) is a promising direction for future evaluation of landslide hazard over slope and lithology based assessments alone.

An approach of preparing earthquake induced landslide hazard map: a case study of Kakani Rural Municipality, Nuwakot District, Central Nepal

***Harish Dangi, and Tara Nidhi Bhattarai**

Department of Geology, Tri-Chandra Campus, Tribhuvan University, Kathmandu, Nepal
**Corresponding author: harishhappy27@gmail.comp*

Earthquake induced landslides are wide-spread in central Nepal after Gorkha Earthquake-2015. Earthquake induced landslide hazard map is useful for decision making including finding safer locations for physical infrastructures development. It also plays an important role in achieving sustainable development.

This research discusses the process of preparing earthquake induced landslide hazard map of Kakani Rural Municipality of the Nuwakot District using QGIS as a major software tool.

Four major disaster factors are taken into consideration which includes, among others, slope inclination, slope direction, relationship with thrust and distance from the epicenter. These factors were classified and characterized according to their nature and condition. Result was analysed by using quantification theory. After the result color representation was done coordinating the range of colors with total points, cumulative relative frequency and situation in the field. To make it user friendly, digital map is made where the user can get GPS coordinates and other relevant information by pointing the certain points in the prepared map. Field verification was done to verify the result with actual ground condition. The map easily differentiates the investigated area into safer zone to hazardous zone with the help of color representation. Result after verification is accurate and this procedure is applicable in such geological condition. This approach is being used to prepare earthquake-induced landslide hazard map of the Nuwakot District.

Landslides triggered by the 2015 Gorkha Earthquake and analysis of their long-lasting impact

***Hikaru Tomita[1], Alessandra Mayumi Nakata[1], Kazuo Konagai[1], Masataka Shiga[1], Takashi Matsushima[2], Takaaki Ikeda[3], and Rama Mohan Pokhrel[4]**

[1] *Institute of Urban Innovation, Yokohama National University, Yokohama, Japan*
[2] *Division of Engineering Mechanics and Energy, University of Tsukuba, Tsukuba, Japan*
[3] *Civil and environmental Eng., Nagaoka University of Technology, Nagaoka, Japan*
[4] *Earth Investigation and Solution Nepal Pvt. Ltd.*
**Corresponding author: tomita-hikaru-vg@ynu.jp*

The 2015 Nepal Earthquake (Mw= 7.8), also called Gorkha earthquake, was the worst natural disaster to hit Nepal since the 1934 Nepal-Bihar earthquake. The earthquake had triggered almost 19,000 slope failures (Gnyawali and Adhikari, 2017). Not only had the landslides taken the lives of so many people, but they had also given a big impact on infrastructures. 18 existing hydropower plants were stopped due to the earthquake and subsequent landslides, resulting in an outage of 171 MW. (Government of Nepal, National Planning Commission, 2015). Furthermore, unstable rock masses still sitting atop of exposed bare slopes will cause long lasting problems. The Trishuli 3A hydropower plant located in Rasuwa district was under construction when the Gorkha earthquake hit. Its construction has often been interrupted since then by the subsequent landslides and its completion has long been delayed for 34 months. This paper attempts to assess the remaining risk of slope failures through numerical simulations and microtremor measurements in areas along Trishuli River near Dhunche, the areas hardest hit by this earthquake.

The numerical simulation used herein is based on a simple mechanical model, which traces initiating, sliding and depositing processes of landslide mass with only three corresponding parameters: the critical angle i_f, Gauckler–Manning roughness coefficient n, and angle of repose i_d. The procedure is based on the idea developed by Nakata and Matsushima (Nakata and Matsushima, 2014) for wide-spread landslide-prone areas where straightforward method to analyze every detail of slope movement is unrealistic for seeing the whole picture of the risk. Through a batch of numerical simulations, the optimum set of parameters was obtained to maximize the estimation accuracy. Further improvement of accuracy was made based on the perception from field surveys. The microtremor measurements were also conducted in the target areas to detect the presence of colluvial deposits.

Given the results of the simulations and field studies, the possible menace of the remaining soil/rock masses is discussed for better and rational rehabilitation strategies. The total volume of hidden and potentially unstable soil masses in one of the target areas of 3.5 km by 2.65 km is calculated to be about 6.2×10^6 m^3. This volume is by far an interim estimation, and only for this particular area. Some debris masses including the one at Ramche are creeping inch by inch (Konagai, et al 2016). Therefore, we cannot keep our eyes off these slopes particularly where major roads cut into already unstable slopes.

REFERENCES

Gnyawali, K. R., and Adhikari, B. R., 2017, Spatial relations of earthquake induced landslides triggered by 2015 Gorkha earthquake Mw=7.8. Advancing culture of living with landslides, v. 4, pp. 85-93.

Government of Nepal National Planning Commission, 2015, Post Disaster Needs Assessment, Vol: B Sector Reports, pp. 141 – 153

Nakata, A.M., and Matsushima, T., 2014, Statistical evaluation of damage area due to heavy-rain-induced landslide, Computer Methods and Recent Advances in Geomechanics (IACMAG), pp. 397–399.

Source mechanism of 2015 Gorkha Earthquake and its biggest aftershock

***Kiran Pandey, Navin Thapa, and Subesh Ghimire**

Central Department of Geology, Tribhuvan University, Kirtipur
**Corresponding Author: Address: pandeykiran80@gmail.com*

The region around central Nepal confronted the devastating Gorkha Earthquake on April 25, 2015 in the portion of the largest active continent collision zone. This event ruptured the interface between the subducting Indian plate and the overriding Eurasian plate. The spatial distribution of aftershocks shows eastward propagation of rupture with the largest aftershock on May 12, 2015 on the easternmost part of the ruptured area.

Estimation of the focal parameters and slip model of these events is done by waveform modeling of the teleseismic P-waves using a multiple event deconvolution method. Results indicate the moment magnitude of the main shock is 7.88 and that of the largest aftershock is 7.24. Total of 28 wave form data for Mw 7.8 and 29 waveform data for Mw 7.24 were retrieved from Wilber and analysed. For the Main event dimension of the fault, rupture area, is assumed to be 190 km x 60 km with rupture velocity of 3.3 km/s. Focal parameters (strike, dip, and rake) of this event are estimated to 282°, 6.4° and 95°, respectively. The biggest aftershock ruptured a fault with dimension 60kmX40km with rupture velocity of 2 km/s. Strike, dip and rake of this aftershock are 287°, 7° and 90°, respectively. Depth and dip constraints estimated in this study indicate these events as interplate events rupturing the Main Himalayan Thrust (or the decollment) at around depth of 11 km.

Structural control of the seismicity in Western Nepal revealed by the Hi-KNET seismological network

***Laurent Bollinger[1], Roser Hoste-Colomer[1,2], Hélène Lyon-Caen[2], Shiba Subedi[2], Mukunda Bhattarai[3], Bharat Koirala[3], Ratna Mani Gupta[3], Thakur Kandel[3], Kapil Maharjan[3], Ramesh Pandey[3], Corentin Quedec[1,3], and Lok Bijaya Adhikari[3]**

[1] *CEA/DAM/DASE, Bruyères-Le-Châtel, France*
[2] *ENS, Laboratoire de Géologie, Paris, France*
[3]*Department of Mines and Geology, Kathmandu, Nepal*
**Corresponding author: laurent.bollinger@cea.fr*

According to historical chronicles as well as preliminary paleoseismological trenches, the latest devastating great earthquake in Western Nepal happened more than 500 years ago in 1505 AD (e.g. Sapkota, 2011). Despite its inescapable repeat in the future, the seismic behaviour of the Main Himalayan Thrust fault segments ruptured during this earthquake are poorly known. Among others, large uncertainties remain on the downdip extent and geometry of the locked fault zone and its lateral variations as well as their relations with large and great earthquake ruptures.

A first temporary seismic experiment, the "Himalaya-Karnali-Network" (Hi-KNet), was therefore deployed for two years in western Nepal in order to image the thrust at depth and reveal the behaviour of the seismicity the region. A total of 15 temporary seismic stations were intalled above the main micro-seismic belts in Chainpur-Bhajang and Karnali region, complementarily to the Regional Seismological Network.

More than 2000 local earthquakes were located below the network during the first year of experiment. Most of these events were clustered within pluri-kilometric long swarms that lasted a few days or weeks. The finest relocations of the local earthquakes reveal a complex pattern of along strike variations of the seismicity. Most clusters develop at the intersection between the megathrust and contacts between Lesser Himalayan tectonic slivers (Fig. 1). Some of the seismic swarms migrate with time.

Altogether, the swarms and individual earthquakes reveal ramps and flat geometry of the megathrust. Some of these structures, among them the largest active ramps, are likely to partially control the rupture of intermediate to large earthquakes.

The structural segmentation revealed by the seismicity leads us to propose a fault model involving intermediate, large and great earthquakes in West Nepal.

REFERENCES

Hoste-Colomer, R., 2017, Variations laterales de sismicité le long du mégachevauchement himalayen au Népal- Phd Thesis, PSL University.

Sapkota, S. N., 2011, Surface rupture of 1934 Bihar-Nepal earthquake: implications for seismic hazard in Nepal Himalaya, Phd Thesis, IPGP.

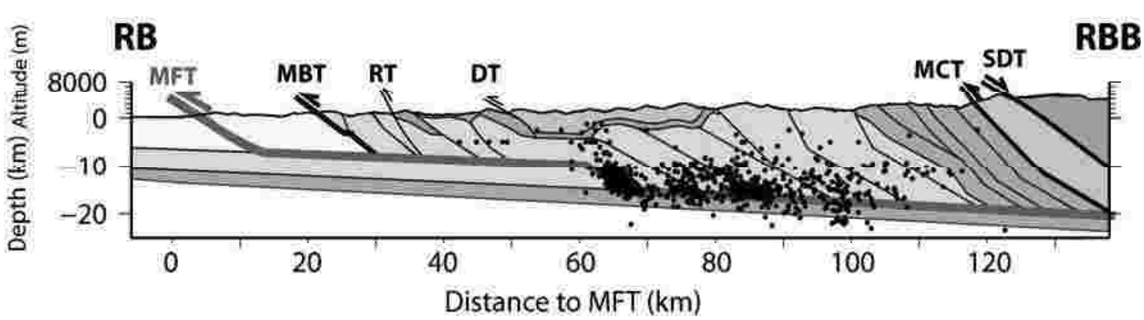


Fig. 1, Chainpur-Bahjang section through the seismicity (Hoste-Colomer, 2017). Black dots correspond to the hypocenters of the local earthquakes located within a 20 km-swath of the Chainpur section in 2015

Geotechnical discussion on the localized deformation in Kausaltar caused by the Gorkha Earthquake, 2015

***Masataka Shiga, Kazuo Konagai[1], Rama Mohan Pokhrel[2], and Takaaki Ikeda[3]**

[1]*Institute of Urban Innovation, Yokohama National University, Yokohama, Japan*
[2]*Earth Investigation and Solution Nepal Pvt. Ltd., Kathmandu, Nepal*
[3]*Department of Civil and Environmental Engineering, Nagaoka University of Technology, Niigata, Japan*
**Corresponding author: shiga-masataka-ft@ynu.jp*

The 2015 earthquake (Mw =7.8), also called Gorkha earthquake, was the worst natural disaster to hit Nepal since the 1934 Nepal-Bihar earthquake. The death toll and the property loss caused by this earthquake are estimated to be 8,891 and $ 7.1 billion, respectively; the latter is almost equivalent to the annual national budget in Nepal (USAID, 2015).

The earthquake had caused severe damage to buildings in the Kathmandu basin. The InSAR (interferometric SAR) imagery from JAXA (Sato and Une, 2016) shows that there are two unique areas with largely disturbed fringe patterns that do not fit the general pattern in Kathmandu basin, which indicates that the entire basin has lifted sloping south. This disturbance of fringe pattern can be attributed to ground deformations localized in these areas. Numbers of buildings and houses collapsed reportedly in one of these area near Durbar Square, while, in the other area in Kausaltar, there appeared ground offsets that had crossed an embankment section of Araniko Highway and the adjacent hill causing massive congestion of traffic through the highway (Konagai et al., 2015). Since these locations are extremely important in the light of municipal performance, thorough investigations into the cause of these ground deformations are necessary for better rehabilitation tactics.

Focusing on Kausaltar, we conduct in-situ tests that include micro-tremor measurements, surface wave tomography and standard penetration tests. Micro-tremors are measured at 10 locations in both seriously and less seriously deformed areas in Kausaltar and 4 more locations near the USGS Kathmandu, and H/V spectra are obtained for all these points. H/V spectra do not show any marked difference between the largely and less seriously deformed areas in Kausaltar. This indicates that the ground deformation might have been more responsible for the damage to buildings rather than the strong ground motion.

Surface wave tomography reveals the presence of two soft soil layers, one with shear wave velocity ranging from 110 to 140m/s spreads 2~4 meters underground over the entire stretch of the target area, while the other spreads 5 m underground only on the lower side of the offset line.

Soil samples from 5 boreholes show that there is a weak organic soil layer 2 to 5 m below the ground surface, which is about 12,000 years old from carbon 14 dating. Several samples below this organic layer are found including very thin tabular sand-filled fissures suggesting the presence of liquefiable layer beneath them. Either or both these layers can be considered to be responsible for the ground deformation in Kausaltar, and there is a need for some follow-up investigations of these soil properties.

REFERENCES

Konagai, K., Pokhrel, R. M., Matsubara, H., and Shiga, M., 2015, Geotechnical aspect of the damaged caused by the April 25th, 2015 Gorkha earthquake of Nepal, JSCE Journal of Disaster Factsheets,

USAID, 2016, Nepal-Earthquake Factsheet #1, Fiscal year.

Sato, H., and Une, H., 2016, Detection of the 2015 Gorkha earthquake-induced landslide surface deformation in Kathmandu using InSAR images from PALSAR-2 data, Earth, Planets and Space, v. 68, n.47, pp. 1–13.

Geomorphological disturbance and damage resulting from the April-May 2015 earthquake sequence in Solukhumbu District (Nepal)

*** Monique Fort [1,4], Narendra Raj Khanal [2,4], Buddhi Raj Shrestha [2,4], and Joëlle Smadja [3,4]**

[1] *Université Paris Diderot, Sorbonne-Paris-Cité, CNRS UMR 8586 Prodig,*
[2]*Department of Geography, Tribhuvan University, Kirtipur, Kathmandu, Nepal*
[3]*Centre for Himalayan Studies, UPR 299. CNRS, 7 rue Guy Môquet, 94800 Villejuif, France,*
[4]*ANR-13-SENV-0005-02 PRESHINE,*
**Corresponding author: fort@univ-paris-diderot.fr*

The unpredictability and low frequency of large earthquakes, together with the disturbance they introduce into geomorphic systems and in the life of local population, should be considered as extreme events. This is illustrated by the example of the recent earthquakes (Mw 7.8 and 7.3) that struck Nepal during April-May 2015. Our study focuses on the eastern margin of the zone affected by the earthquakes, i.e. the Dudh Kosi section (Pharak), an area which straddles the Main Central Thrust zone and the upper Lesser Himalaya, and displays remnants of giant rockslides (Goetz et al., 2015). Methods of investigation include field mapping (before and after the events), cross-checking with satellite images interpretation, and interviews with local people.

Here we stress the role played by earthquake triggered landslides. Main findings are: (1) Though shallow, these landslides permitted a large removal of debris, later amplified by the following monsoon rainfall. (2) Quaternary deposits and unconsolidated material presented higher susceptibility to ground shaking. (3) Large block fields (locally called “Daren”) seem to represent the legacies of former, still undated seismic events. (4) Cascading processes amplified by the following monsoon rainfall ensured the transfer of debris downslope, locally resulting in temporary valley damming and perturbation in regular river flow. (5) Large bank failures along the Dudh Kosi River occurred, and their distribution show that they have reactivated former collapses initiated by another extreme event, the 1985 Dig Tsho GLOF (Fig. 1).

Interviews of the inhabitants and surveys of their house ($n \approx 150$) were conducted. If the age of the buildings and construction quality are obvious parameters to explain the distribution of damaged buildings, other parameters such as the nature and depth of colluvium combined with slope gradient, appear as significant factors susceptible to amplify the effects of ground shaking.

Collectively, the different geomorphic responses we observed have seriously impacted buildings (private and public, shops, tourism lodges) and trails. It also significantly affected water resource and its spatial distribution (drying up or burying of springs, new springs outlet), and produced serious damage to water related infrastructure such as canals, water pipes, water mills and hydropower plants. Adaptations (canal realignment, relocation of mills, etc.) are urgently required in order to maintain agricultural and tourism based livelihood options (a specificity of this area), and to ensure a permanent water and power supply.

REFERENCES

Götz, J., Weidinger, J.T., Kraxberger, S., Hennecke, A.-L., Buckel, J. and Adhikari, B.R., 2015. Geo-morphologic and Hydrogeologic Characteristics of Populated Rockslide Deposits (Sagarmatha National Park, Khumbu Himal, Nepal). Journal of Water Resource and Protection, v. 7, pp. 1038–1048.

Fig. 1, Nakchun terrace, Solu Khumbu, before and after the earthquake (© M. Fort, March 2015 and Oct. 2015)

National seismic network in the aftermath of the devastating 2015 Gorkha Earthquake

***Lok Bijaya Adhikari[1], Bharat Koirala[1], Mukunda Bhattarai[1], Thakur Kandel[1], Ratna Mani Gupta[2], Chintan Timsina[2], Tirtaraj Dahal[2], Kapil Maharjan[2], Eric Sauvage[1,3], Corentin Quedec[1,3], Jean-Baptiste Leblanc[3], and Laurent Bollinger[3]**

[1]*National seismological centre, Department of Mines and Geology, Kathmandu, Nepal*
[2]*Seismological centre, Department of Mines and Geology, Surkhet, Nepal*
[3]*CEA/DAM/DASE, Bruyères-Le-Châtel, France*
**Corresponding author: lbadhikari@hotmail.com*

The National Seismological Center of the Department of Mines and Geology monitors the seismicity in Nepal since 1978 with the technical support from Département Analyse Surveillance Environnement-DASE (France). The number of stations was augmented gradually in the 80s and 90s to create a National Network consisting of 21 short period seismic stations in AD 1998 complemented by a few accelerometric stations and a growing number of Global Positioning System (cGPS) stations.

At the time of the large and devastating Mw 7.8 Gorkha earthquake, on April the 25th 2015, the seismic network was operational and allowed recording and locating the many aftershocks that followed. Some parts of the network and seismic centre suffered –with some damages to buildings- after the Gorkha main shock as well as after May the 12th 2015 Mw 7.3 Kodari earthquake but the stations continued to record and transmit the signals . The network was then fully updated to digital and a new generation of instruments and complemented by 4 broadband stations.

The network allowed monitoring the Gorkha earthquake and the following aftershocks. Altogether, more than 30.000 earthquakes following the main shock were located. Among them, the epicenters and magnitude of the 487 largest earthquakes that triggered the seismic alert (with a local magnitude greater than 4.0) were provided to the authorities, the media and the public between the main shock and September the 21st 2017.

This presentation gives an overview of the national network. It illustrates the work done by the seismologists at the National and Regional Seismic centers after the Gorkha earthquake.

Frequency dependent deformation pattern in Kathmandu Valley due to 2015, Mw 7.8, Gorkha Earthquake

***Navin Thapa, Kiran Pandey, Kamala Kant Acharya, and Subesh Ghimire**

Central Department of Geology, Tribhuvan University
**Corresponding auther: thapasnavin@gmail.com*

Kathmandu valley lies between latitude of 24'032" N to 27'016" N and longitude of 85031'28" E to 85031'53" E. Since the Kathmandu Valley is the parts of collisional orogenic belt, combing rapid crustal shortening and thickening, causes periodic, frequent strong earthquakes. Historical records indicate that the Kathmandu valley has experienced recurring large earthquakes in past centuries. Major damages most probably of seismic origin are dated back to 1255, 1408, 1681, 1803, 1810, 133, 1866, and 1934. The April 25th and may 12th , 2015 earthquake in Nepal present themselves as two major post-instrumentation era events in the Himalayan region and they provide and unprecedented opportunity to study the earthquakes in relation to the seismotectonic settings of the Himalayan convergence.

The study focuses on the dependency of the Kathmandu Valley sediment on frequency of the seismic waves during the Gorkha Earthquake, addresses the influence of local soft valley sediment on incident wave propagation. Structural damage maps from different institutions are collected and pattern of the damage is estimated, based on these maps. The velocity of S wave is considered to be 950m/s based on geophysical studies at different site of valley. Frequency containing high power spectra is calculated from the observed ground acceleration at five stations: TVU, PTN, THM, KATNP, and DMG. Wavelength of the seismic wave propagated during the Mw 7.8 event is calculated using the mathematical relationship between wavelength, velocity and frequency. Thus obtained wavelength is correlated with the observed wavelength on damage data. The investigation reveals that maximum destruction in valley were clustered along the crest of the propagated wave, followed by mild damage and again the clustering of severe damage repeated at the distance of half of the wavelength. This type of severe damage pattern is perpendicular to the wavefront spread out from epicenter towards the direction of propagation, i.e. NE-SW.

Nepal earthquake 25 April 2015: hydro projects damaged, risks and lessons learned for design considerations

Subas Chandra Sunuwar

Freelancer Engineering Geologist, Kathmandu, Nepal
E-mail: sunuwarsc@gmail.com

The 25 April 2015 Nepal earthquake of magnitude 7.8 epicentre at Gorkha and magnitude 7.3 aftershocks on 12 May epicentre at Dolakha had devastating impacts on 14 districts including Kathmandu, capital city of Nepal. Death toll was nearly 9,000 and hundreds of thousands of inhabitants became homeless. The earthquake severely damaged mainly surface structures of hydro projects, access roads, clay mortar stone masonry houses and structurally weak concrete houses. Landslides, rock falls, debris flow, liquefaction, river damming, Landslides Dammed Outburst Flood (LDOF) and Glacial Lake Outburst Flood (GLOF) are expected earthquake-induced hazards. However landslides, rock falls and ground shaking were responsible for major damaged. A total of 15 hydro projects in operations and under construction were affected by the earthquake. In hydro projects more damages were recorded in surface structures such as power house, settling basin, penstock pipes, and diversion weir constructed at base of steep terrains. For instance, surface penstock pipe, lying at base of rock cliff, of running 40 MW Upper Bhote Koshi Project was ruptured by rock falls and flooded surface powerhouse located downstream by water from penstock and headrace tunnel. Similarly diversion weir, surface settling basin and headrace penstock pipe of running 5 MW Mialung Project were severely damaged by landslides and rock falls (Fig. 1). On the other hand, only minor cracking of sprayed concrete at corner and edges in underground structures were observed. In hydro projects there is a practice of considering seismic load in design of structures but the after effects of earthquake induced hazards were not foreseen. This devastating earthquake gave good lessons for design considerations of hydro projects in future. Earthquake risks due to strong ground shaking and earthquake induced hazards are the major lessons learned for design considerations. Seismic design code provides value of Peak Ground Acceleration (PGA) to address risk of strong ground shaking for designing of any structures. On the other hand there are no strict guidelines and design considerations to address and foresee risks of earthquake induced hazards. Therefore, to minimise earthquake induced hazards Seismic hazard assessment; earthquake induced hazards and risks assessment; and protective designs shall be considered as guidelines for design considerations.

Fig. 1, Penstock pipe and settling basin of 5 MW Mailung Project damaged by landslide and rock falls

Hunting for the traces of great Himalayan earthquakes: Lidar Imaging of Nepal's Frontal Thrust's Seismic History

***Soma Nath Sapkota[1], Paul Tapponnier[2], Çağıl Karakaş[2], Paramesh Banerjee[2], Aurelie Coudurier Curveur[2], Sorvigenaleon Ildefonso[2], and Santosh Dhakal[1]**

[1]*Department of Mines and Geology, Kathmandu, Nepal*
[2] *Earth Observatory of Singapore, Nanyang Technological University, Singapore*
**Corresponding author: somanathsapkota@yahoo.com*

Quantifying the seismic hazard and return times of large earthquakes along the Himalayan arc remains a major challenge. Knowing the precise geometry and earthquake rupture histories of active faults is critical to assessing such hazard. Two great historical earthquakes, in AD 1934 (M8.2) and AD 1255 (M>8), have occurred in Central Eastern Nepal, surface rupture of those earthquake were reported in Central Nepal. Surface rupture of 1505 earthquake was also reported at Far-western Nepal. Major portion of the Himalayan Arc is still undiscovered for the past earthquake. There are still many limitations to discover the surface rupture of historical and pre-historical mega-thrust earthquake in this region because scale of the co-seismic throw and limiting depth and paleo-seismological excavations. This makes seismic hazard evaluation more difficult and challenge. Return period of great earthquake in this region is mostly unclear and different group has different interpretation regarding the location and size of historical earthquakes. To study this problem, we have started paleo-seismological research along the Himalayan front. Thus unambiguous answers to simple questions are still pending. How complete is the record for M>8 earthquakes in the region? What faults or fault patches generate such earthquakes and which of the corresponding ruptures reach the surface? To answer these question, we have started series of integrated approach to hunt the past earthquakes. This talk will focus on the result from the airborn LiDAR survey along the frontal part of the Main Frontal Thrust (MFT). Preliminary results from airborne Lidar are promising and shows the characteristic slip in central Nepal.

Journal of Nepal Geological Society, 2017, Vol. 54 (Sp. Issue)

Development of procedure to create building inventory for earthquake loss assessment and risk management

***Suman Pradhan[1], Kapil Bhattarai[2], Deepak Saud[2], Shamir Kumar Singh[2], and Surya Narayan Shrestha[3]**

[1] Structural Engineer, National Society for Earthquake Technology Nepal (NSET), Nepal
[2] Civil Engineer, NSET, Nepal
[3] Deputy Executive Director, NSET, Nepal
**Corresponding author: spradhan@nset.org.np*

The purpose of this study is to develop a method to estimate the quantity of buildings with different seismic vulnerability. In Nepal, it is difficult to get the building inventory data for seismic risk assessment. This paper study the process of creating building inventory with the help of maps and android application in mobile and localizing of structural attributes that are assigned according to building taxonomy of GEM Foundation. Furthermore, it has also focused in more comprehensive classification scheme relevant to seismic performance, e.g. structural system, construction materials and types, criteria of structural layout irregularity etc. which will yield to specific damage patterns and the results of the survey will be utilized in seismic risk calculations to plan future disaster mitigation strategies of the respective municipalities.

An approach to assessing the affordability of landslide risk management strategies for communities affected by the 2015 Gorkha Earthquake in Nepal

***Stephen Revill[1], Tara Nidhi Bhattarai[2], Megh Raj Dhital[2], Kishor Acharya[3], and Lekh Prasad Bhatta[3]**

[1]Technical Advisor, Nepal Operations Center (NPOC), Kathmandu
[2]Department of Geology, Tri-Chandra Campus, Tribhuvan University
[3]National Reconstruction Authority, Land Management and Geological Study Section, Kathmandu
**Corresponding author: revillsr@yahoo.co.uk*

The 2015 Gorkha Earthquake triggered landslides that affected many communities in the central hilly region of Nepal. In the immediate aftermath of the earthquake hundreds of communities many districts were identified as being at risk from earthquake induced or exacerbated landslides.

The National Reconstruction Authority (NRA), Government of Nepal, developed a qualitative methodology for assessing the vulnerability of communities from landslides in conjunction with the Department of Mines & Geology, the Department of Soil Conservation & Watershed Management and the Department of Water Induced Disaster Management. Teams of specialists led by geologists and including civil engineers and watershed management experts were recruited, trained and deployed to undertake geo-hazard assessments at more than 500 communities in 16 districts between December 2016 and July 2017.

Following completion of the survey, measures were initiated by the NRA to help relocate the most vulnerable communities and households where risk management strategies could not be implemented because the hazards were considered too large or too complex to address with practical or affordable means. Attention is now focusing on the implementation of remediation works and risk management strategies for the remaining affected communities.

In the absence of standards to specify design requirements for slope remediation works including longevity, seismic loading and monsoon rainfall levels, significant effort will be required to define the level of remediation or risk management required to provide an acceptable level of long term protection to communities. This paper describes several field reviews of surveys undertaken to demonstrate the complexity of hazards affecting communities and discusses an approach to assessing what could be achieved in terms of long term resilience and residual risk to communities in relation to cost.

In addition to the current post-earthquake reconstruction works, the approach may serve as an aid to the development of a wider integrated landslide risk management strategy for Nepal.

Lessons about landslides and debris flows in the Nepal Himalaya from the 2015 Gorkha earthquake and following monsoons

***A. Joshua West[1], Paul Quackenbush[1], Max Dahlquist[1], Julie Martinez[1], Marin Clark[2], Dimitrios. Zekkos[2], Deepak Chamlagain[3], and Bibek Giri[4]**

[1]*University of Southern California, Los Angeles, CA, 90089, USA*
[2]*University of Michigan, Ann Arbor, MI 48109 USA*
[3]*Department of Geology, Tri-Chandra Multiple Campus, Tribhuvan University, Kathmandu, Nepal*
[4]*Central Department of Geology, Tribhuvan University, Kathmandu, Nepal*
**Corresponding author: joshwest@usc.edu*

The M_w 7.8 Gorkha earthquake in 2015 triggered more than 25,000 landslides, providing a rare opportunity to gain new general understanding of the links between faulting, tectonics, and landsliding. Debris flows in following years caused additional damage and acted to evacuate sediment from landslide-affected hillslopes.

We have focused on an analysis of co-seismic landslide distribution in the Melamchi Khola. Landslides increased progressively from south to north, a trend that is common across fluvial valleys in the earthquake-affected region. Landslide density for catchments in the Melamchi Valley is well correlated with mean catchment slope, relief, and normalized channel steepness (k_{sn}), indicating a strong topographic control on landsliding. These trends are also coincident with decreasing (U-Th)/He ages of apatite and zircon from river sands in tributary catchments, suggesting a fundamental link between tectonic processes controlling exhumation rates and the susceptibility to landsliding in a single forcing event.

The Gorkha-triggered landslides provide a further opportunity to explore the causes and behavior of debris flows. Debris flows associated with the Gorkha earthquake frequently extend into reaches with geometry typically associated with streamflow. We have mapped these debris flows, evaluated whether they are generated by coseismic or postseismic landslides, whether they are likely to be driving active incision into bedrock, and whether their channels correspond with those typically associated with debris flows. Preliminary analysis of these data suggests there may be systematic differences in the geometry of channels containing debris flows triggered by coseismic versus postseismic landslides, which potentially holds implications for hazard analyses and the mechanics behind different debris flow types.

Understanding landscape response to the 2015-Gorkha Earthquake in Northwest Gorkha (western edge of the subsurface rupture zone) for geohazard mitigation and safer reconstruction

***Danda Pani Adhikari[1], and Prem Bahadur Thapa[2]**

[1]*Department of Environmental Science, Tri-Chandra Campus, Tribhuvan University, Kathmandu, Nepal*
[2]*Department of Geology, Tri-Chandra Campus, Tribhuvan University, Kathmandu, Nepal*
**Corresponding author: adhikaridp@ntc.net.np*

Two high-magnitude earthquakes, M_w 7.8 Gorkha earthquake and M_w 7.3 aftershock, struck Nepal on April 25, 2015 and May 12, 2015. The epicenter of the main shock was located close to the village of Barpak in Gorkha about 80 km northwest of Kathmandu. With a hypocenter at about 15 km depth, the earthquakes created a 150 km long and 60 km wide subsurface rupture, and is known to have incompletely ruptured and locked in the Mahabharat range south of Kathmandu (Mencin et al., 2016). The earthquake resulted in about 9,000 casualties and 22,300 injuries and destruction or damage of 784484 homes, in addition to tremendous suffering or loss of livelihoods of hundreds of thousands of people. The total value of disaster effects (damage and losses) caused by the earthquake is estimated at US$ 7.0 billion (GoN, 2015). Gorkha was one of the seven severely hit districts, with 449 casualties, more than 1000 injuries, and damage or destruction of 73222 houses and all 495 school buildings.

Ajirkot Rural Municipality, the western edge of the subsurface rupture zone of the earthquake and area immediately west of Barpak in northwest Gorkha, received little attention of the government agencies and geoscientists, in the aftermath of the earthquake, for the widely held concept that the earthquake only impacted the area east of Barpak, though it took 92 lives, injured hundreds of people and all (3761) houses totally collapsed or left beyond repair. For the devastation to aggravate, the earthquakes triggered widespread shallow landslides, rock falls and avalanches in the mountains, flattened villages and severely damaged or destroyed life lines. Beyond that, mountain slopes in many areas were shattered, fissured and soil tension-cracks formed along the crest of mountains or edge of elevated landforms where communities have been settled for generations. Depths of the cracks and fissures were not well known but they were kilometers long. In the face of ongoing disaster recovery, geohazard concerns to the mountain communities, such as renewed landslide, subsidence, slope failure and rock fall from the mountain slopes that have fissures and soil tension-cracks, have created a lot of confusions for resettlement decisions though the affected areas did not experience much adverse geological changes, as expected, during the last three summer monsoons.

The main objective of this study was to understand landscape response to the 2015-Gorkha earthquake in Ajirkot Rural Municipality area for geohazard mitigation and safer reconstruction.

The Ajirkot area was investigated for landslides, soil tension-cracks and other instabilities. With respect to the geohazard condition in the aftermath of the 2015-Gorkha earthquake, the area lies at various points along a stability spectrum ranging from high margins of stability with low probabilities of failure (e.g. Low hazard zone, LH) at one end to actively failing slopes, with little or no margin of stability (e. g. high-very high hazard zone, H-VHH) at the other. There are marginally stable slopes, not currently undergoing failure but are susceptible to failure at any time (e. g. medium hazard zone, MH), somewhere between LH zone and H-VHH zone. In all cases, geological and engineering geological conditions are the main factors of instability.

In over all, Kharibot, Hansapur, Simjung and Muchchok areas have safe areas for reconstruction compared to Ghachchok area. Reconstructing houses in MH and HH-VHH zones need special attention, i.e. it requires very detailed site-specific investigation. There were few or no new landslides and reactivation of earthquake-induced landslides and soil tension-cracks in the last three summer monsoons, but it may not be correct to assume that there will be no more geohazard questions in future. All the landslides and cracks need to be monitored for couple of years to see how they changes if future loss and damage associated with them are to be reduced.

REFERENCES

GoN, 2015, Nepal Earthquake 2015: Post Disaster Needs Assessment, V. A: Key Findings, National Plannining Commission, Nepal, 123 p.

Mencin, D., Bendick, R., Upreti, B. N., Adhkari, D. P., Gajurel, A. P., Bhattarai, R. R., Shrestha, H. R., Bhattarai, T. N., Manandhar, N., Galetzka, J., Knappe, E., Pratt-Sitaula, B., Aoudia, A. and Bilham, R., 2016, Gorkha earthquake hints at reservoir of mid-Himalayan strain pending release in future great ruptures. Nature Geoscience (doi:10.1038/NGEO2734).

If poorly constructed buildings are the major source of earthquake risk, fix the buildings: lessons learned from Nepal's Gorkha Earthquake sequence of 2015

Amod Mani Dixit

National Society for Earthquake Technology–Nepal (NSET)
E-mail: adixit@nset.org.np

The Nepal Gorkha Earthquake sequence of 2015, with a magnitude MW 7.8 and with a maximum intensity of IX MMI, revealed all prevalent vulnerabilities, and confirmed the righteousness of the proactive approaches of step by step risk reduction, especially in developing country. The following lists the major learnings:

a) Main strategy for reducing earthquake risk is to stop building up vulnerabilities, reduce existing vulnerabilities, and prepare for residual risks; b) Poorly constructed non-engineered masonry buildings are the major sources of earthquake risk; a combination of traditional indigenous knowledge and modern science and technologies can help improve seismic performance of new as well as existing buildings; c) Earthquake awareness and education are the key elements in earthquake risk management; a good basic awareness on earthquake can dispel many unwanted myths and unproductive indulgence on the possible usefulness of short-term earthquake prediction; d) Schools are the best places to demonstrate the efficacy of earthquake risk reduction: messages on earthquake risk management and preparedness taught in schools gets propagated into the society by the process "from teachers to students – from students to parents, and from parents to the community"; and e) Prevalence of non-engineered buildings in developing countries demands special approach in vulnerability reduction and building code implementation – training of masons and petty contractors is as important as training and education of building engineers.

The Gorkha earthquake was "unusual" in terms of consequences. The death toll and building destruction was much lower than what was anticipated. There may be various reasons for this, however, persistent efforts on earthquake risk reduction in the past two devades was definitely a reason for this "lucky" end result.

The superposed sawtooth model of suspended sediment concentration in the Yellow River subaqueous delta based on observation

Chaoqi Zhu[1], and *Yonggang Jia[1,2]

[1]*Shandong Provincial Key Laboratory of Marine Environment and Geological Engineering, Ocean University of China, Qingdao,China*
[2]*Laboratory for Marine Geology, Qingdao National Laboratory for Marine Science and Technology, Qingdao, China*
**Corresponding author: yongang@ouc.edu.cn*

The time series of waves, tides, currents, temperatures, turbidities were measured for 134 days in the Yellow River subaqueous delta by submarine in situ tripod with various instruments (Zhu et al., 2017a; Zhu et al., 2017b). The samples taken from the study site were analysed in the laboratory to obtain the sediment grain size and the relationship between the suspended sediment concentration and turbidity. The laboratory test results show that the sediment is mainly silty, and there exists a good linear relationship between the suspended sediment concentration and turbidity. The observation results show that the suspended sediment concentration varies from 2 g/l to 4 g/l in the Yellow River subaqueous delta (Fig. 1). Both the in-situ observation and the shear stress show that the sharp rise in suspended sediment concentration is attributed to the episodic high waves, and the quotidian currents are responsible for the periodic fluctuation in suspended sediment concentration. Above all, a superposed sawtooth model of suspended sediment concentration influenced by waves and currents is proposed and the shear stress can explain the reason why episodic waves account for big sawtooth and currents are responsible for the small sawtooth.

REFERENCES

Zhu, C., Jia, Y., Wang, Z., Guo, L., Shan, H., Liu, X., and Zhang, M, 2017a, Dynamics of Bottom Boundary Layers in the Yellow River Subaqueous Delta Based on Long-Term In-Situ Observations, Acta Geologica Sinica-English Edition, v. 91, pp. 369–370.

Zhu, C., Liu, X., Shan, H., Zhang, H., Shen, Z., Zhang, B., and Jia, Y, 2017b, Properties of Suspended Sediment Concentrations in the Yellow River Delta Based on Observation, Marine Georesources and Geotechnology, v. 35, pp. 1–11.

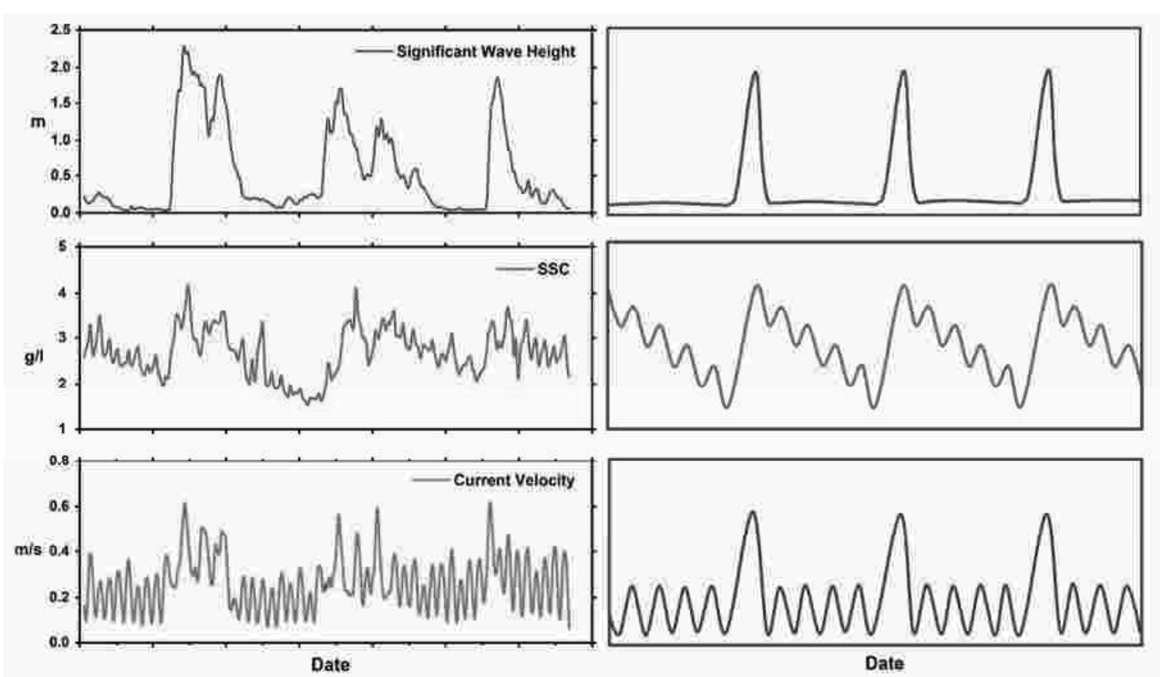


Fig. 1, Superposed sawtooth model of suspended sediment concentration

Contribution of wave-induced liquefaction in triggering hyperpycnal flows in Yellow River Estuary

***Xiaolei Liu[1,2], and Yonggang Jia[1,2]**

[1]*Shandong Provincial Key Laboratory of Marine Environment and Geological Engineering, Ocean University of China, Qingdao, China*
[2]*Laboratory for Marine Geology, Qingdao National Laboratory for Marine Science and Technology, Qingdao, China*
**Corresponding author: xiaolei@ouc.edu.cn*

Hyperpycnal flows, driven mainly by the gravity of near-bed negatively buoyant layers, are one of the most important processes for moving marine sediment across the earth. The issue of hyperpycnal flows existing in marine environment has drawn increasing scholars' attention since that was observed in situ off the Yellow River estuary in the 1980s (Wright et al., 1988). Most researches maintain that hyperpycnal flows in the Yellow River estuary are caused by the high-concentration sediments discharged from the Yellow River into sea (Fig. 1); however, other mechanisms have been discounted since the sediment input from the river has been significantly changed due to climate and anthropogenic change (Wang et al., 2016).

Here we demonstrate that wave-seabed interactions can generate hyperpycnal flows, without river input, by sediment flux convergence above an originally consolidated seabed. Using physical model experiments and multi-sensor field measurements, we characterize the composition–dependent liquefaction properties of the sediment due to wave-induced pore water pressure accumulation. This allows quantification of attenuation of sediment threshold velocity and critical shear stress (predominant variables in transport mechanics) during the liquefaction under waves. Parameterising the wave-seabed interactions in a new concept model shows that high waves propagating over the seabed sediment can act as a scarifier plough remoulding the seabed sediment. This contributes to marine hyperpycnal flows as the sediment is quickly resuspended under accumulating attenuation in strength. Therefore, the development of more integrative numerical models could supply realistic predictions of marine record in response to rising magnitude and frequency of storms.

REFERENCES

Wang, S., Fu, B., Piao, S., Lu, Y., Ciais, P., Feng, X., and Wang, Y., 2016, Reduced sediment transport in the Yellow River due to anthropogenic changes, Nature Geoscience, v. 9, pp. 38–41.

Wright, L.D., Wiseman, W. J., Bornhol, B.D., Prior, D.B., Suhayda, J.N., Keller, G.H., and Fan, Y.B., 1988, Processes of marine dispersal and deposition of Yellow River silts by gravity-driven underflows, Nature, v. 332, pp. 629–632.

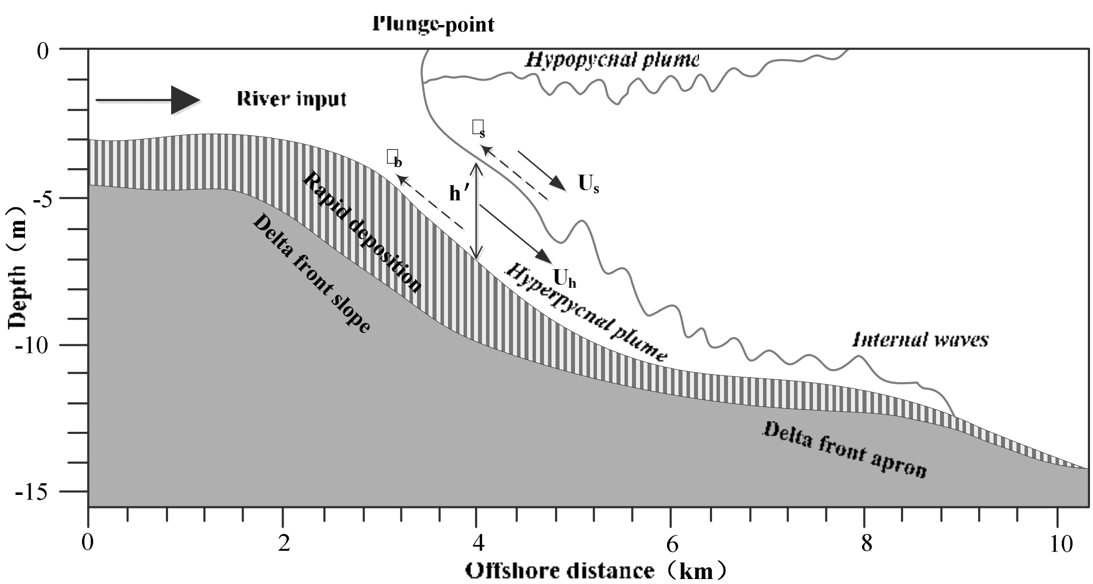


Fig. 1, Schematic diagram of a plunging hyperpycnal flow in Yellow River Estuary

In-situ observation of submarine landslide process in the delta of Yellow River

***Yonggang Jia[1,2], Zhenhao Wang[1,2], and Xiaolei Liu[1,2]**

[1] *Shandong Provincial Key Laboratory of Marine Environment and Geological Engineering, Ocean University of China, Qingdao, China*
[2] *Laboratory for Marine Geology, Qingdao National Laboratory for Marine Science and Technology, Qingdao, China*
**Corresponding author: yonggang@ouc.edu.cn*

Submarine landslides move large volumes of sediment and are often hazardous to offshore installations. Current research into submarine landslides mainly relies on marine surveying techniques. In contrast, in situ observations of the submarine landslide process, specifically seabed deformation, are sparse, and therefore restrict our understanding of submarine landslide mechanisms and the establishment of a disaster warning scheme. The Submarine Landslide Monitoring (SLM) System, which has been designed to partly overcome these pitfalls, can monitor storm-wave-induced submarine landslides in situ and over a long time period. This study recorded the development of the SLM System and the results of in situ observation in the Yellow River Delta, China, during the boreal winter of 2014–2015. The results show an abrupt small-scale storm-wave-induced seabed shear deformation; the shear interface is in at least 1.5 m depth and the displacement of sediments in 1.23 m depth is more than 13 mm (Fig. 1). In addition, a wave-flume experiment about wave-induced shear failure was supplemented to show the failure process. Results of the experiment show that arc shaped sliding surface inside the seabed would appear after a certain wave loading time，and the failure soil did oscillatory motion along the interface. A hard layer developed beneath the sliding surface and eventually resulted in nonhomogeneous strength of seabed. The shear failure of seabed directly controlled the formation and evolution of the hard layer.

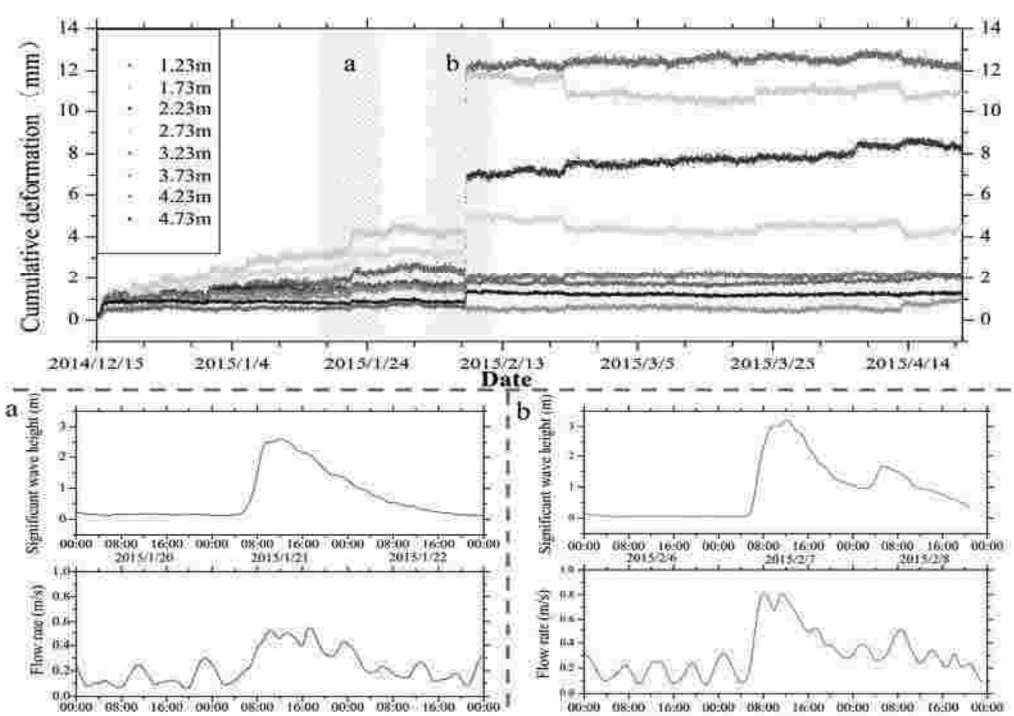


Fig. 1, Time series of cumulative horizontal deformation (mm) of the shape accel array (SAA) from 15 December 2014 to 14 April 2013 (colours denote seabed depth), attached with the significant wave height and flow rate from 20–22 January 2015 (a) and 6–8 February 2015 (b).

Physical and mechanical properties of loess discharged from the Yellow River into the Bohai Sea, China

Hong Zhang[1], *Yonggang Jia[1, 2], Xiaolei Liu[1, 2], Chaoqi Zhu[1], and Hongxian Shan[1, 2]

[1]*Shandong Provincial Key Laboratory of Marine Environment and Geological Engineering, Ocean University of China, 266100 Qingdao, China*
[2]*Key Laboratory of Marine Environmental & Ecology, Ministry of Education, 266100 Qingdao, China*
**Corresponding author: yonggang@ouc.edu.cn*

Chinese loess is unique in having great scientific value whilst also playing an important role in societal development. The Chinese Loess Plateau is one of the birthplaces of the Chinese nation. According to the statistics of the geological hazards in China, there are almost one third of cases in this area. Large volumes of loess are continually carried by the Yellow River from the Chinese Loess Plateau to the Bohai Sea, northeast China, forming the Yellow River Delta. The physical and mechanical properties of this loess vary during transportation, and these characteristics have been investigated in detail using several samples of estuarine loess collected from tidal flats with different depositional ages (Fig.1).

The physical and mechanical properties of these samples have been determined through laboratory tests. Our results show that the estuarine loess is classified as silty loess, and that its specific gravity, plasticity, and grain size characteristics were very similar to land-derived loess. Its unit weight and water content increased during discharge into the sea, and its plastic index decreased. The estuarine loess also had fewer large pores that were more closely connected than those in land loess. As a result of these changes in index properties, estuarine loess is less susceptible to liquefaction than land-derived loess, which can be obtained from the dynamic triaxial test. As for the mechanical properties, the shear strength resistance of estuarine loess is lower than that in land loess. And the estuarine loess can be classified as secondary compression soil like the land-derived loess. In addition, these physical and mechanical properties show strong correlations to the long-term depositional history of the delta, with older deposits typically having a lower dry density and higher void ratio than younger deposits.

The results of this study have implications for hazard mitigation and improving our understanding of the mechanisms responsible for loess-related geological disaster.

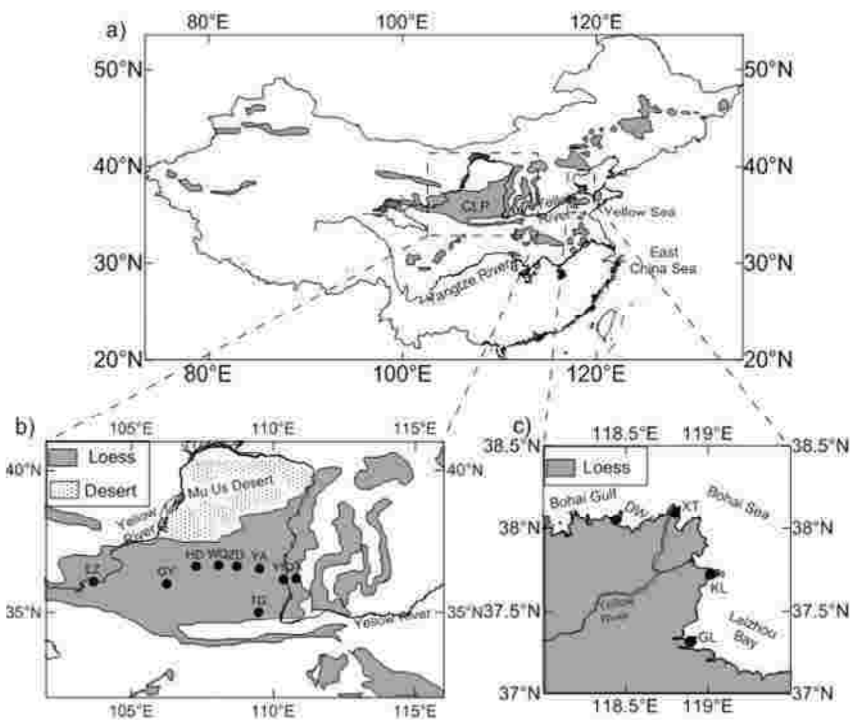


Fig. 1, a) Distribution of loess deposits in China and location of the study region of the Yellow River delta. CLP refers to the Chinese Loess Plateau. b) Chinese Loess Plateau and location of some of the sites mentioned in the text. c) Location of the studied loess sections in the Yellow River delta (Dawang = DW, Xintan = XT, Kenli = KL, and Guangli = GL)

Accurate determination of the basic friction angle of rock using the tilt test

Hyun-Sic Jang, and *Bo-An Jang

Department of Geophysics, Kangwon National University, Chuncheon, Republic of Korea
**Corresponding author: bajang@kangwon.ac.kr*

Samples of Hangdeung granite from Korea and Berea sandstone from the USA, both containing sliding planes, were prepared by saw-cutting or polishing using either #100 or #600 grinding powders. Their basic friction angles were then measured directly by direct shear testing and triaxial compression testing, and also indirectly by tilt testing.

Angles measured by direct shear testing on the polished planes of granite created using #100 and #600 grinding powders (hereafter, the #100 plane and #600 plane, respectively) were similar at 29.2° and 28.6°, respectively. However, the angle measured on the saw-cut plane was 25.5°, which is about 3° smaller than for the polished planes. Angles measured on the #100 plane and the saw-cut plane of the sandstone were similar, being 35.1° and 34.6°, respectively. When measured on the #600 plane the angle was 26.4°, which is about 8° lower than that for the other two types of surface. The basic friction angle for the granite, as measured by triaxial compression testing, was 29.5° for the #100 plane, 28.8° for the #600 plane, and 25.2° for the saw-cut plane. The values for the sandstone were 33.1° for the #100 plane, 27.9° for the #600 plane, and 32.3° for the saw-cut plane. All the angles measured on the #100 plane were similar, but those measured on the other planes varied with the measuring method. Therefore, the basic friction angles were determined by averaging the values measured on the #100 planes and were 29.4° for the granite and 34.1° for the sandstone.

In the tilt testing, the sliding angles, which are considered equivalent to the basic friction angles, were measured 50 times. The first angles measured were about 40° regardless of rock type (this is higher than the basic friction angle measured by direct shear testing and triaxial compression testing). For the polished planes the values then tended to decrease following a negative exponential curve as the measurements continued. The angles measured on the 50th repetition were always lower than the basic friction angle from the other tests. However, when measured on the saw-cut plane, the sliding angles were almost constant or tended to decrease linearly. The sliding angles were different from the basic friction angles, and the differences between two adjacent measurements were large. Averages of sliding angles at 10, 20, 30, 40, and 50 repetitions on the #100 plane of the granite ranged from 23.5° (for 50 repetitions) to 31.1° (10 repetitions). Those on the #100 plane of sandstone ranged from 28.2° (50 repetitions) to 36.9° (10 repetitions). The average sliding angles measured over 20 repetitions were similar to the basic friction angles measured in direct shear tests and triaxial compression tests.

As the tilt tests were repeated, the sliding planes were abraded to form a plane that became progressively easier to slide, meaning that sliding angles were reduced. Errors may be introduced by air pockets trapped between the two sliding planes when the #600 planes were used in tilt tests. The waviness of sliding planes may cause a large difference between sequential measurements when saw-cut planes are used in tilt tests.

These results indicate that the basic friction angle of rock can be accurately determined by tilt tests when planes polished with #100 grinding powder are used and the average of 20 measurements is taken.

Deformation and failure analysis of surrounding rock basing on borehole stress measurements and numerical simulations

***Qinghong Dong, Kun Song, and Wenhao Li**

School of Resources and Geosciences, China University of Mining and Technology, Xuzhou, China
**Corresponding author: dongqh@126.com*

The deformation and failure zones formed by mining are important parameters for design, safety and environment evaluation. Changes of rock mass structure and stress/strain variations are often used to interpret the mechanism and process of deformation and failure. The paper basing on the drilling in-situ stress tests and numerical calculations, a set of comparative analysis method has established to distinguish the top edge of the fissured zone above the mined out area. This works has been done according to the geological conditions of 3111 working panel in Zhuang coal mine, Anhui, China.

Two inclined boreholes were arranged in one side of the work face and bias to the goaf zone, which have the angles of 10 to 15 degrees with the roadway and are tilted at an angle of 30-60 degrees aiming to extend to the top of the mined out area (Fig. 1). The length of them are always 5-10m longer than the empirical value. After completion of drilling about 60 days before mining, a plurality of tension and compression stress sensors are pushed into the boreholes by PVC pipes. The annular gap then is consolidated by injection of cement. The distances of the sensors are 1-2 m in vertical ensuring the position identification error is no more than ±1 m. All the preparation works should finished at least one month before mining in order to gain the dynamic stress data from the begging to the ending changes of the axial stress. Once or twice times observations every day should be guaranteed.

According to the geological conditions of the same mining face, a numerical model has been established and calculated. The observation line is set at the same location of the borehole. The stress evolution at different depths in the borehole appears basically the same rule. The axial stress of the borehole has a period of changing process. From its beginning to the end, the axial stress shows a differentiation phenomenon and reaches s the peak values at a certain position. The boundaries of differentiation in the depths of the borehole are very similar of the two results, and this is very close to the empirical value of the height water fractured zone. This method is a useful route to obtain the situations of deformation or failure of surrounding rock during mining.

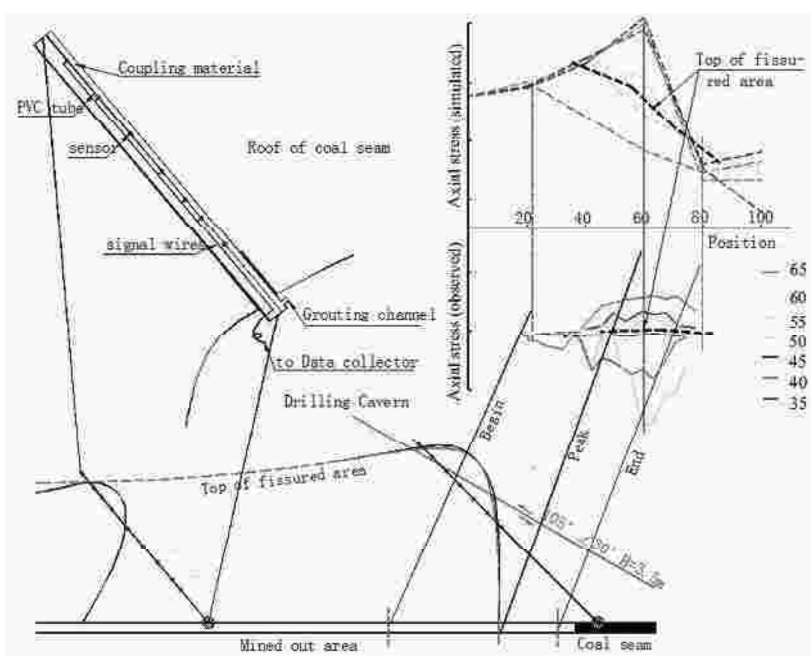


Fig. 1, Borehole stress method to observe the fracture zone height in coal mine

Field-based assessment of rock discontinuity analysis and geological attributes particularly of stones for various engineering applications

***Sunita Bhattarai[1], and Naresh Kazi Tamrakar[2]**

[1]*Deparrment of Mines and Geology, Kathmandu, Nepal*
[2] *Central Department of Geology, Tribhuvan University, Kirtipur, Kathmandu, Nepal*
**Corresponding author: sunitabhtry.828@gmail.com*

Because of the occurrence of various rock types within the short span of areas the Malekhu Khola area is one of most promising areas where potentiality of stones is high. This paper presents the study and recognition of the most promising rock types in terms of their geology and discontinuity for evaluating their suitability for various stones. The research focuses on the assessment of eight different rock types allocated along the Malekhu Khola. Geological parameters, rock mass characterization and discontinuity analysis were carried out in each of allocated sites. During field study, rock masses were categorized based on different geological parameters (Bieniawski, 1989), and based on number of joint sets, tentative block shape, size and volume were computed. Field-based data were tabulated, analysed and finally identified for the block size and geometry, and rock mass quality for stones.

The study shows that the rock types vary from poor to very good. The number of major joint set ranges from one to four with random joint sets. The study shows that the outcrop condition of rock is faintly to slightly weathered, strongly indurated, and the Rock Mass Rating (RMR) system ranges from poor to very good rocks. The block type that could be extracted are long, flat and compact (Fig. 1), respectively. The probable end uses of these rock types could be armorstone, interior and exterior paving, cladding, and foundation.

REFERENCES

Bieniawski, Z.T., 1989, Engineering Rock Mass Classifications. John Wiley & Sons, New York, British Geological Society, 2005, Mineral Profile, Building and Roofing Stone, Natural Environment Research Council, 251p.

Palmström, A., 1995, RMi – A Rock Mass Characterization System for Rock Engineering Purposes. PhD thesis, University of Oslo, Department of Geology, 400 p.

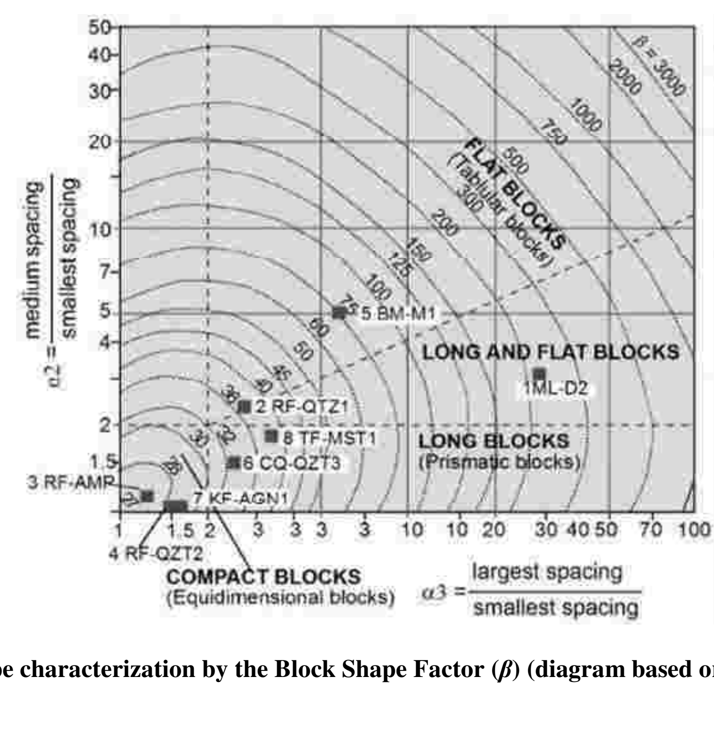


Fig. 1, Block shape characterization by the Block Shape Factor (β) (diagram based on Palmström, 1995)

Influence of Barton's joint roughness coefficient on grout propagation during injecting into a permeated fracture

***Wanghua Sui, and Jialu Xiong**

School of Resources and Geosciences, China University of Mining and Technology, Xuzhou, China
**Corresponding author: suiwanghua@cumt.edu.cn*

This paper presents some experiments carried out to study the influence of roughness of fractures on sealing effect of hydrodynamic grouting. The effects of fracture roughness on water shutoff rate, grout propagation and retaining, seepage pressure in fracture were studied. Based on the Barton's standard roughness grade profile curve, 10 sets of simulation test with different roughness fracture grouting were carried out. The grout propagation morphology of grouting in rough fractures is divided into two types: the near-circular propagation of the whole-moving type and the near-rectangular propagation across the displacement type. When the joint roughness coefficient JRC ≤8, the grouting propagation morphology is nearly circular propagation of the whole-moving type, and the pre-propagation process of the grouting is similar to the propagation process of the straight and smooth fracture under the same conditions. When the joint roughness coefficient JRC >8, the grouting propagation morphology near the rectangular propagation across the displacement type. Fracture roughness has a great influence on the propagation distance and propagation area of the grout. The smaller joint roughness coefficient is, the more favorable the propagation of the grout. The greater the joint roughness coefficient is, the more difficult the propagation of the grout.

The curves of water flow changes of grouting into different roughness fracture are analyzed in the parallel test. The curves of water flow changes is divided into three categories: single peak decreasing type and multi-peak fluctuating and double platform type. It can be seen from the water shutoff rate, when the joint roughness coefficient JRC ≤ 10, the grouting effect belong to the type of "failure" and "very poor" level. And when JRC > 10, the water shutoff rate is better than that in the situation of JRC ≤ 10.

In the experiment, the factors influencing the effect of grouting and water shutoff were followed by the gel time, joint roughness coefficient and hydrodynamic velocity. In the single fracture grouting test with flowing water, the joint roughness coefficient of the fracture determines the overall type of grout propagation, while the hydrodynamic flow rate and the gel time have little effect on the grout diffusion morphology when the joint roughness coefficient is small. When the joint roughness coefficient is large, the greater the flow of water, the longer the gel time, the more serious crushing of the grout, blocking the worse. When the flow rate is minimum, the grout will flow to the reverse flow rather than the direction of the flow. Joint roughness coefficient has a great influence on the change of water flow during grouting, while the change of hydrothermal velocity and the gel time has little effect on the change of water flow during grouting.

Steep slope stability analysis of open rock quarries in Istanbul, Turkey

***Murat Yılmaz[1], Altay Ertin[2], Selman Er[1], and Atiye Tuğrul[1]**

[1]*Department of Geological Engineering, Istanbul University, Avcılar, Istanbul, Turkey*
[2]*Geo-Net Engineering & Consulting, Farabi Sk. 13/5, Ankara, Turkey*
**Corresponding author: yimazm@istanbul.edu.tr*

The key question regarding steep rock slopes along rock quarries is their stability for safety production because a rock slope failure can have critical results. In this study, the aim is to investigate the areas with potential risk for jointed karstic limestones in a rock quarry. First, to determine rock mass properties, scan-line surveys were performed, and the major orientations of discontinuities were analyzed using stereographic projection. Then, the physico-mechanical properties of the slope-forming rock were determined in the laboratory, and geomechanical properties of the rock mass were determined using an empirical failure criterion. Finally, the quarry slope stability was assessed in accordance with numerical modelling.

According to the results obtained, the numerical modelling of steep rock slopes can be efficiently evaluated by using finite element method. Beside this, the presence of joints intersecting the main discontinuity sets, the filling materials of discontinuities resulting from weathering of limestone and surface deposits, surcharge load due to mine waste dumped on the slopes and excavation blasting during construction of quarry area play a key role when modelling the steep rock slopes by using finite element method.

Geo-Ethical Issues in Landslide Monitoring Systems: Indian Context

***Pratik Chaturvedi[1], Ravindra Singh Bora[2], and Surya Parkash Gupta[3]**

[1]*Defence Terrain Research Laboratory, DRDO, Delhi, India*
[2]*National Disaster Management Authority, Delhi, India*
[3]*National Institute of Disaster Management, Delhi, India*
**Corresponding author: prateek@dtrl.drdo.in*

Landslide Early Warning System (EWS) is a common practice for understanding the risk potential of a problematic slope. Researchers have applied various approaches to find the probability of occurrence of landslides on regional as well as site-specific scale. On regional scale, rainfall thresholds along with landslide hazard zonation maps are used worldwide to find the risk of landslides. While in a site-specific landslide problem, generally geophysical, geotechnical and geological survey is first carried out to identify the weaker zones and triggering phenomenon and after that sensors based monitoring of the slope is done. But the study of landslide monitoring practices in India reveals that most of these approaches use same sensors (e.g., inclinometers, piezometers and extensometer along with tipping bucket rain gauges) for monitoring different types of landslide processes. However, the causative and controlling factors for different types of landslides have been found to be different depending on the material and failure process involved in the movement. Each of these landslide process is governed by different factors but during the development of landslide monitoring systems by many of the researchers, same set of sensors have been used. Expensive sensors and instrumentation used without understanding the material and processes enhance the errors and uncertainties in landslide monitoring. These kinds of landslide monitoring systems cannot be used reliably by the planners, administrators, development agencies, communities and other stakeholders. Also, this approach is likely to affect the credibility of the scientists working in the field of landslide monitoring. Hence, it is proposed that standard operating procedure (SOP) for landslide site specific monitoring systems should be generated to improve the current status of landslide monitoring systems in India. It will also help in establishing some good practices and monitoring infrastructure that may help cater for better understanding each landslide characteristics more accurately. This will ultimately result in estimating potential landslide probabilities with greater reliability so as to create robust site specific landslide prediction models. Thus, the greater reliability and accuracy of the landslide monitoring studies will boost the confidence and trust of the society and governance in scientific practices.

The paper emphasizes that there is a need to better understand the natural phenomena/processes like landslides, plan and monitor them using appropriate scientific technology depending on the scale and level of work, implement and infer with more reliability and accuracy (while highlighting the limitations and uncertainties) so that the predicted probabilistic state or behavior of the slopes should match well with the real/actual conditions.

Risk understanding and measures undertaken to be prepared for future earthquake event in the aftermath of 2015 Gorkha Earthquake in the Pokhara Valley

***Chandani Bhandari[1,2], and Ranjan Kumar Dahal[3]**

[1]*Institute of Crisis Management Studies, Tribhuvan University, Nepal*
[2]*Geotech Solutions International, Kalika Marga, Lalitpur, Nepal*
[3]*Central Department of Geology, Geodisaster Research Center, Tribhuvan University, Nepal*
**Corresponding author: chandanibhandari09@gmail.com*

Nepal is earthquake-prone country and earthquakes in Nepal have been documented since 1255. Recent 2015 Gorkha Earthquake measuring Mw 7.8 occurred at 11:56 AM Nepal Standard Time on 25 April 2015 with an epicenter 77 km northwest of Kathmandu at the Barpak Village of Gorkha District and killed about 9000 people.

After this devastating earthquake, people became aware of the drawbacks and lacking part of the country for disaster risk management. However, the Western part of Nepal has not experienced the earthquake for more than 200 years after 1803 (Uttarkashi) and 1833 Nepal's earthquake. (Bilham et al., 1997). According to Bilham et al. (1997), the occurrence of one or more earthquake in the western part of Nepal can release > 6 m of co-seismic displacement, similar to other M> 8 Himalayan events that have occurred in the past 100 years.

This paper is based on the Pokhara valley i.e. the western part of Nepal which is more prone to disasters such as earthquake, floods, landslides, land subsidence and sinkholes. Data are collected through various social surveys and technical interviews. This paper will describe the level of understanding of people about disaster risk in the Pokhara Valley and what brought about the change in people's perception of risk posed by the recent extreme disaster event i.e, 2015 Gorkha Earthquake. The preliminary data analysis suggested that people are taking the recent earthquake as a past event and its future occurrence is very low. Hence, it will also give a brief information on people not being aware of the risk associated with the use of building codes, sinkhole free area for settlement and settlement on debris flow fan.

REFERENCES

Bilham. R, Larson. K, Freymueller, J., and Project Idylhim members, 1997, GPS Measurements of Present-Day Convergence across the Nepal Himalaya, CIRES and Department of Geological Sciences, University of Colorado, Boulder, Colorado 80309, USA.

Empirical models for predicting the spatial variation of soil thickness and shear strength for landslide susceptibility assessment

***Cheryl F. Daleon[1], and Glen A. Lorenzo[2]**

[1,2]*Graduate School of Engineering, Mindanao State University-Iligan Institute of Technology (MSU-IIT), Iligan City, Philippines*
**Corresponding author: cheryl_daleon@yahoo.com.ph*

Landslides are the most widespread natural hazard on earth and had been a problem of many countries worldwide. In the Philippines, landslides are among the major geologic hazards that resulted to thousands of lives lost and millions of pesos of economic damage over the years (Opiso et al., 2014). Thus, in a country that is mostly hilly and mountainous, utilization of land on slopes is inevitable. It is therefore very important to map out unstable areas in order to ensure the safety of the people and delineate suitable areas for development.

On the other hand, spatial variation of soil thickness, cohesion and friction angle are crucial in large scale slope stability analysis for landslide susceptibility assessment. However, determination of these parameters is challenging, costly and time consuming. In order to opt out expensive laboratory tests and laborious field investigation, efforts had been done by many researchers to predict these parameters over large areas. In this study, the soil samples and soil thickness data are gathered from 30 sampling boreholes and 60 probed points in an area with Pliocene-Pleistocene geologic description. The details on slope angle are obtained from the slope map through a processed Digital Elevation Model (DEM) in Geographic Information System (GIS) particularly the ArcGIS software. Slope angles are confirmed in the site through actual measurement using the clinometer. The soil thickness is measured from the ground surface down to the interface of soil and weathered bedrock. The cohesion and friction angle are determined from the direct shear test. Regression analysis is used to establish an empirical models correlating the soil thickness and shear strength parameters with the slope angle. The result revealed that the slope angle has yielded better correlation to the soil thickness than the cohesion and friction angle. The resulting slope angle-soil thickness empirical model was validated from ten different sites with similar geology.

REFERENCES

Opiso, E. M., Puno, G. R., Detalla, A. L., and Alburo, J. P., 2014, Rainfall-induced landslide susceptibility zonation along the Cagayan de Oro City–Bukidnon–Davao City Route Corridor, Technical Report, Central Mindanao University, Bukidnon, Philippines.

Mechanism analysis of sinkholes formation at Jili village, Laibin city, Guangxi province, China

***Jianling Dai, Weiquan luo, Yuanbin Wu, and Xiaozhen Jiang**

Institute of Karst Geology, CAGS, Guilin 541004，Guangxi Province, China
Key Laboratory of karst collapse prevention, CAGS, Guilin 541004，Guangxi Province, China
**Corresponding author: daijianling@karst.ac.cn*

After an extreme rainstorm event on June 1 2010, 20 sinkholes took place at the Jili village, Laibin city, Guangxi province in a month. The impact area occupied more than 1500 m^2. Three of the sinkholes expanded and merged gradually and eventually developed into a large sinkhole which is 170 m long and 38 m deep. It is the largest sinkholes in Guangxi province. In order to understand the formation mechanism, extensive investigations including field investigation, three-dimensional laser measurement, geophysical prospecting, exploratory boreholes, real-time monitoring of karst water pressure and rainfall and geotechnical test of soil samples were conducted. The results indicated that sinkholes at Jili village were natural causes. It is the result of a combination of multiple adverse factors. These factors mainly include the special "water-soil-rock" combination and extreme rainstorm. The special geological conditions determined the particularity of the sinkholes. Analysing the formation process and mechanism of the sinkholes, we think they were mainly controlled by the combination of gas explosion effect, water hammer effect and seepage erosion effect.

Journal of Nepal Geological Society, 2017, Vol. 54 (Sp. Issue)

Liquefaction-induced damage to residential houses and its effects to health problems of residents in the 2016 Kumamoto earthquake in Japan

Yuko Serikawa[1], and *Masakatsu Miyajima[2]

[1]Graduate School of Science and Engineering, Kanazawa University, Kanazawa, Japan
[2]School of Environmental Design, Kanazawa University, Kanazawa, Japan
**Corresponding author: miyajima@se.kanazawa-u.ac.jp*

Mw 6.2 earthquake struck in and around the Kumamoto City in Japan at a depth about 11 km at 21:26 JST on April 14, 2016. Around twenty eight hours later, at 01:25 JST on April 16, an Mw 7.0 stronger earthquake occurred in the same area at a depth of about 12 km. More than 8,000 houses were totally collapsed. Total fatality after the main shock was 49 dead with 1 missing. The main shock triggered many geo-hazards such as landslides, surface faulting and liquefaction. This study is focusing on liquefaction problem appeared in this earthquake.

Liquefaction-induced damage to residential houses was not caused over a wide range in the stricken area but in the band like range. Fig. 1 shows an example of inclination of houses induced by liquefaction at Chikami in the Kumamoto City. Differential settlement of houses was occurred and the inclination of houses caused health disorder of the residents. Field investigation and inspection were conducted to study an effect of inclination of the residential houses due to liquefaction to health problems of residents in this study.

The inclination angle of 68 houses and buildings in liquefied sites of the Kumamoto City was measured. Fig. 2 shows the distribution of the number of damaged houses by inclination angle. Previous studies have revealed the influence of inclination of houses on health condition, and it is known that dizziness and associated sickness gradually occur when the inclination angle exceeds 1/100 (0.6°). Approximately 30% of the surveyed houses are inclined to 0.6° or less, while the remaining about 70% is the inclination amount related to health problems.

The effects of inclination of houses on health problems were investigated by interview to residents lived in the inclined houses. The symptoms of health disorders were headache, back pain, dizziness, towing feeling and so on. Many of the symptoms developed within about one month after the earthquake, and it has not cured even after one year in bad case. From such a current situation, it can be said that the inclination of houses caused by liquefaction is serious problem.

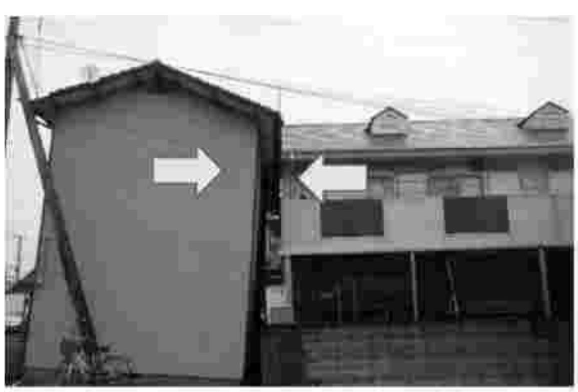


Fig. 1, Inclination of houses at Chikami in Kumamoto City

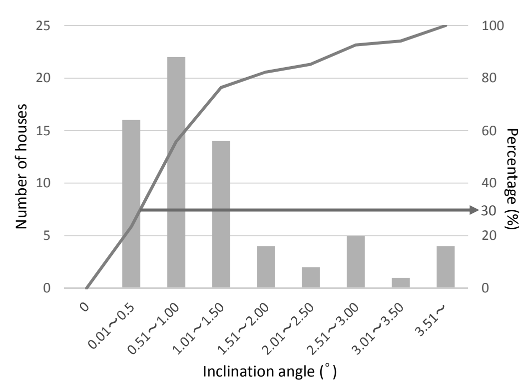


Fig. 2, Histogram of the inclination angle

Towards effective and sustainable disaster risk management in Nepal: challenges and gaps

Ramesh Tuladhar

Freelanscer, DRM and M&E Specialist, Kathmandu, Nepal
E-mail: r.tula1950@gmail.com

Geo-hazards-vibrant Himalayan tectonics, high seismicity, predominant soft rock (argillaceous) formations, steep slopes, rugged (high elevation difference) terrain, when mistreated would trigger disasters. These natural factors exacerbated by unplanned developments together with impacts of global climate change has further scaled-up disasters in Nepal. Common natural disasters in Nepal are due to the earthquakes, floods and landslides that impact the livelihoods of the people most. The earthquakes have long periodicity (+/- 70 years return period) but catastrophic while the floods and landslides are recurrent (almost every year during the monsoon) and chaotic.

Substantial efforts have been made on disaster risk reductions (DRR) both by the state and non-state organizations and continue to do so. Contributions from sectoral ministries lead by the Ministry of Home Affairs are primarily focused to legal provisions, strategies and policies while the departments are mandated to implement sectoral activities through projects and programs. Overwhelming rescue and relief operations immediately after 2015 mega-earthquake demonstrated solidarity by national, bilateral and international organizations. Post-earthquake recovery and rehabilitation activities are continuing. However, despite all these DRR efforts, outcomes are not satisfactory to the desired extent whether the disasters are of earthquakes or floods or landslides across the country as per media reports.

This paper aims to analyse some key questions towards effective and sustainable DRM in Nepal through the lens of efforts made against challenges and gaps. Also in the backdrop of Sendai Framework for DRR 2015-2030, a theory of change that would help improve effectiveness and sustainability of DRM in Nepal is envisioned and discussed.

Liquefaction countermeasure of groundwater level lowering method installing permeable pipe by jacking methods

***Takao Hashimoto[1], and Tositaka Shimizu[2]**

[1]*Faculty of Science and Engineering, Kokushikan University, 4-28-1, Setagaya, Tokyo 154-8515, Japan*
[2]*Construction Engineering, Mainmark Aquatek Co., Ltd. 5-2-3, Nishikasai, Edogawa, Tokyo 134-0088, Japan*
**Corresponding author: thashimo@kokushikan.ac.jp*

Many housing were damaged by liquefaction in the Chiba City Mihama ward by the Great East Japan Earthquake. The road was filled with sand boil, and housing land sank and inclined. Car sank into sand, and was prevented from moving. In generally, open-cut method using crushed stone and pipe has been adopted as liquefaction countermeasure. Open-cut method was used for the first time in the Amagasaki city in the Great Hanshin-Awaji Earthquake, the next was used in Yamamoto estate in the Niigata-ken Chuetsu-oki Earthquake. Even now, there is no clogging and is continuing to lower groundwater level safely. Because Ibaraki and Chiba Prefecture caught the liquefaction damage in the Great East Japan Earthquake, open-cut method was adopted in the Itako city and the Kamisu city. But, open-cut methods in urban area have to move buried pipe, so other methods were required.

Therefore, we have been developing new groundwater level lowering method installing permeable pipe (φ 300 mm) by jacking methods under road. Pipe material is polypropylene, and outside diameter of 30 cm, inner diameter 20 cm, length 1 m. There is impermeable sheet to prevent flow of dirt for tube circumference, and there is geotextile for the surrounding. Experimentation of the new method have been tested and analysed at a local park in the Chiba city from October 14, 2014 to July 31, 2015. Construction procedures are shown. Firstly, the sheath pipe is pushed from shaft to following shaft by using induction pipe. Secondly, a drain pipe is inserted. Thirdly, sheath pipe is removed. Lastly, manhole is connected.

Water level in the north-south direction was compared by groundwater level prior to pumping and after pumping. Even when the position of the drainage pump was raised to a depth of 3.5 meters, the groundwater in the covered conduits and the area in between was 2.74～2.84 meters. This indicates that draining was effective. Water level in the east-west direction was compared by groundwater level prior to pumping and after pumping. Groundwater level in the conduits and the part in between them, and the conduit in between dropped to a depth of 2.66 to 2.84 meters. This indicates that drainage was sufficiently effective. Water depth contour shows that it dropped uniformly.

The experiments and analyses showed the jacking method to be just as effective for the lowering of the groundwater level as the open-cut method. After being reviewed by the Liquefaction Countermeasures Committee, the new method was adopted for Chiba City. And, the construction method was given as an effective method in "Metropolitan liquefaction countermeasures promotions guidance" issued by the Metropolis Bureau of the Ministry of Land, Infrastructure, Transport and Tourism in January 2016. It was also awarded the Technology Prize of the Kanto Branch of the Japanese Geotechnical Society.

Mechanical characterization of rock materials with reference to assigned weathering grades: problems and promises

Arindam Basu

Department of Geology & geophysics, Indian Institute of Technology Kharagpur, India
E-mail: abasu@gg.iitkgp.ernet.in

The ongoing process of weathering in nature produces progressive but intricate changes in rock microstructure at shallow depths where most engineering works are confined, especially in tropical and sub-tropical areas. Evaluating mechanical behaviors of rock materials with reference to weathering grades is, therefore, important for an engineering work encountering decomposed rocks. However, assigning weathering grades to rock materials is a challenging task. The descriptions and classifications of weathered rocks for engineering purposes has remained a subject of debate since engineering geologists first produced standards and codes. This study first focuses on the salient points of the common 6-fold weathering classification of rock materials and subsequently, with examples from different parts of the world, demonstrates how far the use of index tests can substantiate the weathering grades of rock materials assigned based on the subjective 6-fold classification. This is followed by mechanical characterization of the concerned rock materials with reference to the assigned grades. The mechanical response of these rock materials under different states of stress in relation to the degree of decomposition is also explained (Fig. 1).

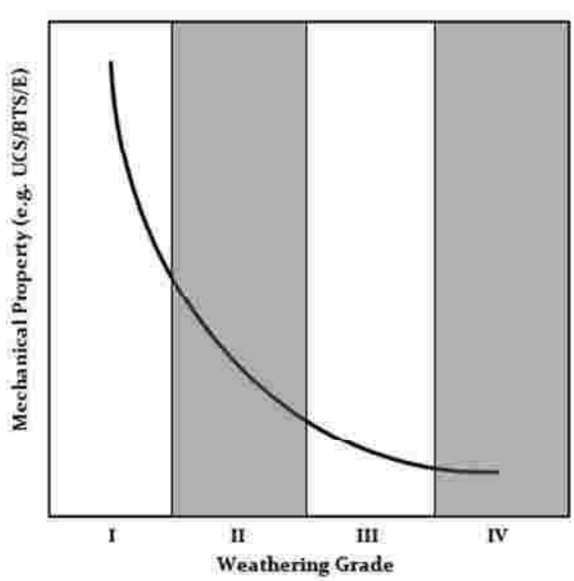


Fig. 1, General trend of deterioration of rock mechanical properties with reference to weathering grades

Evolution of weathering characteristics according to weathering grade of granites in Sejong, Korea

***Ik Woo[1], and Jeong Gi Um[2]**

[1]Department of Architecture and Coastal Construction Engineering, Kunsan National University, Kunsan, Korea
[2]Department of Energy Resources Engineering, Pukyung National University, Busan, Korea
**Corresponding author: woo@kunsan.ac.kr*

Granite is important in geotechnical aspect, due to its large superficial coverage in Korea. Some of granite degrade considerably in engineering time to lead finally an engineering structure to unstable conditions. That's why this study focuses on the weathering characteristics of granites distributed in Sejong city, Korea, in function of time by means of the laboratory accelerated weathering tests. For this purpose, the accelerated artificial weathering tests were conducted in laboratory for rock core specimens of granite with different weathering grades selected from boreholes: weathering grades of specimens corresponding to F MW and HW. First of all, physical and mechanical properties were measured in order to classify the rock specimens according to their weathering grade, such as the P-wave propagation velocity, the absorption ratio and the shore hardness by Equotip tester. The initial properties would be served as criteria for classifying rock specimens with their weathering grades and also comparing with the properties measured after weathering tests (Woo et al., 2013). In addition, XRD and XRF analysis were carried out to identity the dynamic mineralogical transition with weathering processes. And then the accelerated artificial weathering tests had been conducted for one-month. Mineral analysis indicates that the amount of clay minerals, such as vermiculite and illite, is increased with weathering and that the content of biotite and feldspars is decreased with weathering. The content of feldspars particularly such as plagioclases and k-feldspars is decreased rapidly when the weathering progresses from MW (moderately weathered) to HW (highly weathered) since plagioclase prone to chemical weathering alters to be kaolinite which would eventually be washed out from its original place. CIA diagram (Fig. 1) shows the dynamic evolution of major constituent minerals of corresponding granite.

Accelerated artificial weathering tests were designed to reflect the Korean climatic condition which has, in general, four distinct seasons–spring, summer, fall and winter. Modified freeze-thaw tests have been, therefore, adopted for this study: one cycle consists of 12 hours in acidified solution of H_2SO_4 and HCl and consecutive 12 hours in freezer under 25^oC below zero. One-month's artificial weathering tests reveal the general degradation of physical properties in granite specimens including P-wave propagation velocity and the absorption ratio. The degradation of the physical properties in the granite of HW was larger than that of F or MW. The uniaxial compressive strength (UCS) was increased on the contrary by the weathering tests (Fig. 2). The measurement for physical properties were restricted on the outer surface of the specimens, while the mechanical properties could concern the entire rock including outer and inner part of specimen. Test results allow to consider that the mechanical properties would not be degraded during the engineering time, whereas the conditions of rock surface could be altered such as the surface of excavated rock slope and joint surface so that the stability of rock structure can be affected in the engineering time.

REFERENCES

Woo, I., Kim, J. G., Lee, G. H., Park, H. J. and Um, J. G., 2013, Evaluation of the impact of pyrite oxidation on rock characteristics and environment by laboratory. Environmental Earth Sciences, v. 69(6), pp. 1821–1829.

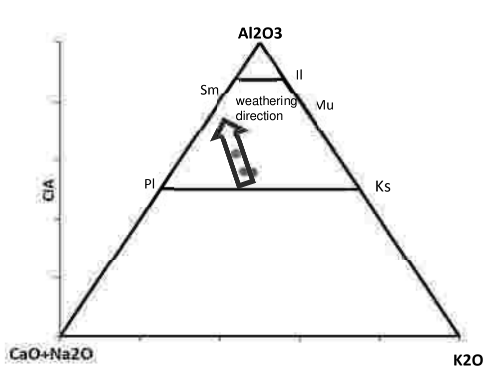


Fig. 1. CIA diagram for weathering progress of granite

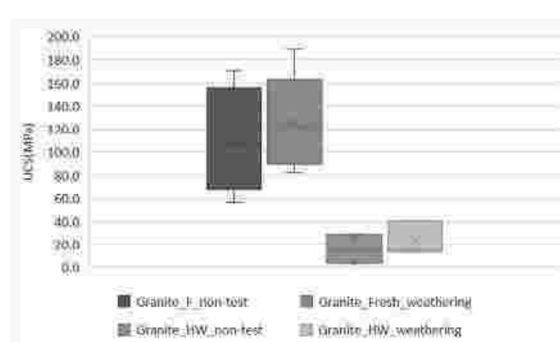


Fig. 2. Variation of UCS by artificial weathering tests

Assessment of the utility of improved slaking index test for characterizing Some clay-bearing sedimentary rocks in Indonesia

***Imam A. Sadisun[1], Misbahudin[1], Indra A. Dinata[1], and Hideki Shimada[2]**

[1] *Department of Geological Engineering, Institut Teknologi Bandung, Bandung, Indonesia*
[2] *Department of Earth Resources Engineering, Kyushu University, Fukuoka, Japan*
**Corresponding author: imam@gc.itb.ac.id*

Important contribution to the study on the slaking process of argillaceous rocks have recently highlighted the possibility on representing of their behavior within a suitable test. This test extends to the concepts of slake progression initially developed for weak rock materials by introducing a dependency of slaking index parameter (Santi, 1998; Sadisun et al., 2002).

With regard to abovementioned concern, an improved method of static slaking index test as suggested by Sadisun et al. (2002; Fig. 1) was carried out in this study with regard to assess better utility of the test for some clay-bearing sedimentary rocks in Indonesia. Some samples taken using block sample method were collected as a case study, in which they were then classified as claystone, siltstone, mudstone and shale due to their lithologic characteristics. The results show that some modifications to the slaking index test reduced the variability of testing results, offering considerable improvement in its consistency and reproducibility. For routine identification of durability characteristics, it is suggested that the slaking index values be determined on 100-150 grams of rock lumps with the duration of soaking for about 12 to 16 hours. Satisfactory results were obtained in the use of tap water as adequate and simple alternative to highly treated distilled water. The result data analysis was further improved by determining the progression of slaking through five cycles of the test and implementing observation indexing, resulting in a new index called slake-susceptibility index (SSI). To be suitable for the engineering purpose, the test indicates certain criteria, such as simple, rapid and inexpensive to perform, as well as yielding meaningful and reproducible results which can further reflect natural durability characteristics.

REFERENCES

Sadisun, I. A., Shimada, H., Ichinose, M. and Matsui, K., 2002, Improved Procedures for Evaluating Physical Deterioration of Argillaceous Rocks, Proc. 2nd Intl. Conf. on New Development in Rock Mech. and Rock Eng., Shengyang, P. R. China, Rinton Press, pp. 36–39.

Santi, P. M., 1998, Improving the Jar Slake, Slake Index, and Slake Durability Tests for Shales, Environmental and Eng. Geoscience, v. 4(13), pp. 385–396.

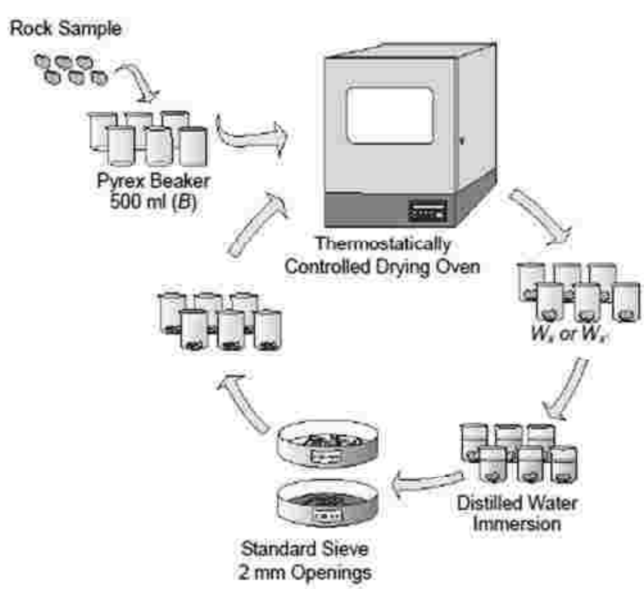


Fig. 1, Schematic diagram of improved slaking index test

In-situ direct shear testing (Block Shear Test) at Tanahu Hydropower Project, Tanahu District Western Development Region, Nepal

Madan Raj Pokharel

Tanahu Hydropower Limited, Trade Tower, Thapathali Kathmandu, Nepal
E-mail: madanrajpokharel@gmail.com

Tanahu Hydropower Limited (THL) is a subsidiary company of Nepal Electricity Authority (NEA). The Project site is situated 150 km west of Kathmandu on Seti River near Damauli of Tanahu District in Gandaki Zone. Tanahu Hydropower Project is the storage type of project having installed capacity of 140 MW. The in-situ Direct Shear Tests were conducted at the powerhouse drifts AP-2 site of Tanahu Hydropower Project with 05 different blocks sheared in three consecutive normal loading stages. The peak shear strength and residual shear strength data shows that cohesion of rock mass C_{peak} is 0.52 MPa & C_{res} is 0.51 MPa and friction angle of rock mass shows that Phi_{peak} is 38.7^0 and Phi_{res} 37.0^0. RMR rating System (After Bieniawski, 1989) is used to calculate the rock mass rating and support design. Based on Bieniawski, 1989 rock mass rating of cohesion of rock mass greater than 0.51 MPa -0.52Mpa is placed in class I to class II (very good rock to good rock) and friction angle of rock mass ranges between 37.0^0 – 38.7^0 is placed Class II (good rock). The rating value shows that rock of that area is under class II (good rock), excavation: full face, 1-1.5 m advance; complete support 20 m from face. Rock bolt (20mm diameter, fully grouted): locally, bolts in crown 3m long, Spaced 2.5 with occasional wire mesh. Shotcrete: 50 mm in crown where required.

Depositional environment and directional movement of debris flow sediments of Ratmate area, Sindhuli, central Nepal

Milan Kumar Rai, Nitesh Subedi, Prakash Khanal, Sanjay Rizal, *Ranjan Kumar Dahal, and Suman Manandhar

Central Department of Geology, Tribhuvan University, Kirtipur, Kathmandu
**Corresponding email: rkdahal@gmail.com*

Nepal is the country of topography diversity, it consists of high mountains hills and also a flat land like Terai. Mainly mountainous and hilly region faces the problems according to the topographical and depositional environment like landslide, slope failure, rock fall, flood, debris flow etc. Among them debris flow sediments and residual soils was observed in the Ratmate area of the Sindhuli District, Central Nepal.

The residual soil deposited at the Ratmate area on right bank of the Sunkoshi River which is characterized by different associated depositional environment. Evidence supports that the deposition was formed by the mega earthquake induced landslide dam on southern part of it along the Khurkot area.

At the same time debris activity in the Ratmate area is well observed. Most of the deposited material of that area are deposited by debris flow and formed fluvio-lacustrine deposit. Columnar section shows the residual deposit reflects the variable diameter of boulders ranged from fine soil up to 1 m. The thickness of the columnar section along the road section varies from 1.8 m to 6.5 m. The rose diagram of the pebble imbrications shows that the flow direction of debris towards southwest.

The composition of most of the pebbles and cobbles observed in the section belong to granite, amphibolite, meta-sandstone, schist and phyllite.

The upper most part of lacustrine red soil is characterized by sandy and clayey deposits. The soil characteristics of residual soil is Silty Sand (SM), High plastic Silt (MH) with having high strength and highly permeable. Thus it may create the problem in rainy season on the highway as well as in other infrastructures.

Determination of representative volume element at the Songta dam site

Shengyuan Song, and *Qing Wang

College of Construction Engineering, Jilin University, Changchun, Jilin, China
**Corresponding author: wangqing@jlu.edu.cn*

The Songta Hydropower Station is located in the southeast of the Chayu Country of Tibet in China (Fig. 1). The power station is the first of twelve to be constructed in the upper and middle reaches of the Nu River. Due to the long-term geological effects, a larger number of discontinuities are widely developed within the rock mass of dam abutment. The spatial distribution of discontinuities is stochastic and complex. Therefore, the shear strength, deformation modulus and permeability coefficient for the fractured rock mass gradually vary with increasing of sample size. When the sample size is greater than a certain critical value, the equivalent parameter is basically stable. The critical value is the representative volume element (RVE) size (Long, et al., 1982). The existence of RVE is a prerequisite for the study of fractured rock mass using the continuous medium method. Thus, determination of RVE is very important to ascertain the parameters of rock mass and calculate the stability of rock slope.

The size of RVE obtained from different research aspects is different. That is to say, every parameter will correspond to a RVE. The more the parameters are considered, the greater the value of RVE is, as well as the more the representative of the equivalent parameters and the applicability of the continuous medium method are assured in engineering applications. In addition, the mechanics, deformation and hydraulic properties of a rock mass not only depend on the geometry and strength of many individual discontinuities but also are related to the geometric position of all discontinuities. Hence, the RVE determined based on the comprehensive characteristics of discontinuities is more universal and practical.

The discontinuity persistence, the connectivity degree of the discontinuities along a given plane, depends on the discontinuity orientation, size, position and density (Xing, 1989). The persistence is firstly proposed in the seepage of fractured rock masses, and subsequently applied to the stability evaluation of rock slope. In a word, the persistence can comprehensively reflect the geometric, mechanical and seepage characteristics of fractured rock masses. Thus, a new method for identifying the RVE size based on the discontinuity persistence is proposed in the study.

REFERENCES

Long, J. C. S., Remer, J. S., Wilson, C. R., and Witherspoon, P. A., 1982, Porous Media Equivalents for Networks of Discontinuous Fractures. Water Resources Research, v. 18, pp. 645–658.

Xing, Z., 1989, A Two-Dimensional Model of En-Echelon Jointed Rock Masses with Multi-Discontinuity Geometry Parameters. Rock Mechanics and Rock Engineering, v. 22, pp. 231–242.

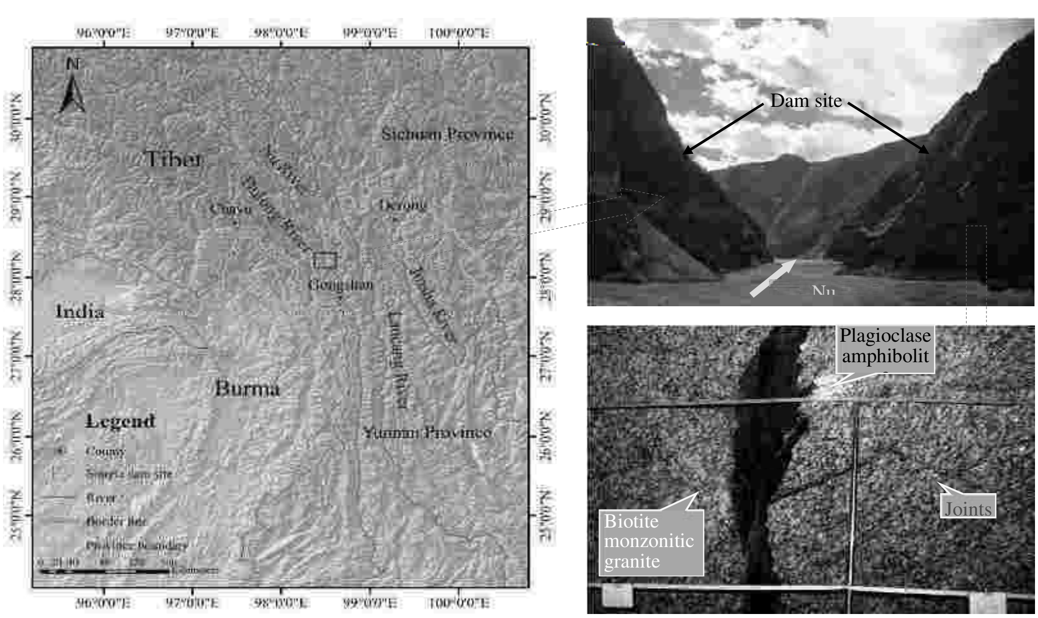


Fig. 1, Position and geological conditions of the Songta Dam site

Dynamic behavior of the peaty soils in Kayseri Free Trade Zone (Turkey) and comparison of their site response with two seismic codes in Europe

***Nazlı Tunar Özcan[1], Reşat Ulusay[1], and Nihat Sinan Işık[2]**

[1]*Hacettepe University, Department of Geological Engineering, Ankara, Turkey*
[2]*Gazi University, Faculty of Technology, Civil Engineering Department, Ankara, Turkey*
**Corresponding author: ntunar@hacettepe.edu.tr*

Peats are problematic soils because of their high water content, high permeability, high organic content and extremely compressible nature. When compared to some other countries such as Canada, Russia, Malaysia and Indonesia, peatlands are not common in Turkey. One of the most typical peatlands in Turkey is at Ambarköy and its vicinity at the west of Kayseri which is one of the biggest cities. In the study site, the peat layers are considerably shallow-seated with thickness ranging from 5 to 8 m. Their water and organic contents are between 72-376%, 23-59%, respectively.

By considering the presence of the active faults in close vicinity of Kayseri and the rapid growth of industrial facilities on the peaty soils in this city, determination of the dynamic properties of peats in the Kayseri Free Trade Zone and investigation of their seismic site response are aimed in this study. For these purposes, shear wave velocities of the peat were determined with in-situ seismic measurements and dynamic properties, which are the inputs for the dynamic analyses, were obtained from resonant column tests. Then site response analyses were conducted and the results were compared (Fig. 1) with the design spectra recommended for loose-soft soils by the Turkish Seismic Design Codes (TSDC, 2007) and European Construction Design Codes (EC 8) (Bisch et al., 2011).

The measured shear wave velocities of the peat layers are between 35 and 60 m/s. A maximum PGA of 0.28 g was estimated for the study site based on the nearest fault segment using the attenuation relationship developed for Turkey by Ulusay et al. (2004). By considering the seismic characteristics of the study site and its vicinity and dynamic properties of the peats five input ground motions were selected from the PEER's (Pacific Earthquake Engineering Research Center) database. Then, seismic ground response analyses were performed by using the Deep soil V6.0 (Hashash et al., 2015) with the input parameters. The analysis results indicated that the peats in study site will attenuate the earthquake waves at low periods. But at the periods greater than 0.3-0.5 second, they will cause an increase in soil amplification. As it can be seen from the Fig 1, the response spectra of the investigated peats are not compatible with those recommended by the two codes in Europe. In other words, the amplification levels of these peats are greater than those recommended in both codes.

REFERENCES

Bisch, P., Carvalho, E., Degee, H., Fajfar, P., Fardis, M., Franchin, P., Kreslin, M. Pecker, A., Pinto, P., Plumier, A., Somja, H., and Tsionis, G., 2011, Worked Examples Presented at the Workshop "EC 8: Seismic Design of Buildings", Lisbon, 10-11 Feb, 2011.

Hashash, Y. M. A., Musgrove, M. I., Park, D., Tsai, C. C., Phillips, C. A., Groholski, D. R., 2015, DEEPSOIL 6.0, 1-D Wave Propagation Analysis Program for Geotechnical Site Response Analysis of Deep Soil Deposits.

TSDC, 2007, Specification for Buildings to be Built in Seismic Zones, Ministry of Public Works and Settlement Government of Republic of Turkey, Amended on: 3.5.2007, Official Gazette no.26511.

Ulusay, R., Tuncay, E., Sönmez, H., and Gökçeoğlu, C., 2004, An Attenuation Relationship Based on Turkish Strong Motion Data and Iso-Acceleration Map of Turkey, Engineering Geology, 74, 265–291.

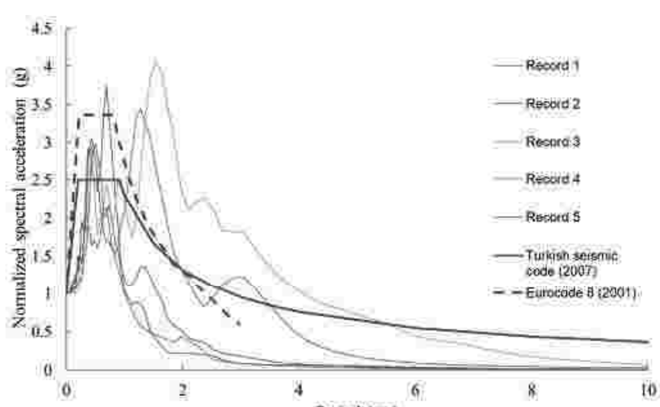


Fig. 1, Comparison of the peat's response spectra and design spectra suggested by TSDC and Eurocode 8

Journal of Nepal Geological Society, 2017, Vol. 54 (Sp. Issue)

Study on the geochemical characteristics and weathering behaviour of black shale

***Xin Liao[1], Xiyong Wu[1,2], Qingfeng Wang[1], Sixiang Ling[1], and Chunwei Sun[1]**

[1]*Department of Geological Engineering, Southwest Jiaotong University, Chengdu, China*
[2]*MOE Key Laboratory of High-Speed Railway Engineering, Southwest Jiaotong University, Chengdu, China*
**Corresponding author: xinliao@swjtu.edu.cn*

Black shale weathering plays a significant role in the engineering constructions. This process is mainly dependent on the chemical and mineral constituents, especially on the sulfide minerals. The black shales sampled from three provinces in southwest China are analysed comparatively. Geochemical characteristics and chemical index of alteration (CIA) of these black shales are examined (Alpers and Nordstrom, 1999). Based on the different weathering behaviors of black shale distributed in different geological environment, the influence factors forming various weathering products are discussed. Among the weathering products, sulfate and clay minerals are the most important components, as well as the acidic water (Chigira and Oyama, 1999). Attribution to the chemical weathering of black shale, engineering hazards and environmental pollutions are analysed. Moreover, the corresponding engineering prevention measures are proposed to provide reference.

REFERENCES

Alpers, C. N., and Nordstrom, D. K., 1999, Geochemical Modeling of Water–Rock Interactions in Mining Environments, In: Plumlee, G. S., Logsdon, M. J. (Eds.), The Environmental Geochemistry of Mineral Deposits. Part A: Processes, Methods and Health Issues, in Reviews in Economic Geology, v. 6A, pp. 289–324.

Chigira, M. and Oyama, T., 1999, Mechanism and Effect of Chemical Weathering of Sedimentary Rocks. Engineering Geology, v. 55, pp. 3–14.

Engineering geology of cross-Himalayan railway alignment and its preliminary design

***Zhen-ming Shi[1], Yuan-yuan Zhou[1], Wei-ran Liu[1], Qing-zhao Zhang[1], Dan-xuan Xue[1], and Megh Raj Dhital[2]**

[1]*Department of Geotechnical Engineering, Tongji University, Shanghai, China*
[2]*Department of Geology, Tri-Chandra Multiple Campus, Tribhuvan University, Ghantaghar, Kathmandu, Nepal*
**Corresponding author: shi_tongji@tongji.edu.cn*

The One Belt-One Road initiative foresees the construction of transportation routes across continents. One of such railway routes is planned from Tibet (China) through the Himalayan Range to Nepal and India, and envisaged to be one of the most important economic corridors. Based on the field investigation, this paper analyzes the engineering geological conditions along the proposed route and proposes a preliminary design of the alignment. The alignment starts from Dingri via Jilong and ends in Kathmandu, with a total length of 357 km. Based on the geological and geomorphic characteristics, the alignment can be divided into five zones: the mid mountain and wide valley, mid mountain and narrow valley, alluvial fans, tunnel crossing and alpine gorge. The railway alignment encounters glaciers, snow and rock avalanches, collapses, landslides, outburst floods and debris flows. There are also many faults, folds and other geological structures together with steep and extensive slopes and long tunnels with a high overburden.

Geological challenges of road construction in Trishuli Valley between Syafrubensi and Betrawati, Lesser Himalaya, Central Nepal

***Akash Acharya, and Megh Raj Dhital**

Department of Geology, Tri-Chandra Campus, Tribhuvan University
**Corresponding author: achakash@hotmail.com*

The Himalaya is one of the youngest mountains in the world. The mountain range is quite unstable and geomorphologically dynamic because of profound tectonic activities. Due to complex tectonics, these mountains suffer from frequent earthquakes. On the other hand, intense precipitation triggers landslides and floods. Hence, the construction of transportation routes can markedly increase the geo risk in the Himalayan setting where roads involve excavation and the construction of embankments in the locations already in the state of critical stability. A minor change in the slope geometry or groundwater conditions can have a notable impact on local ground conditions. The study area lies to the north of Kathmandu valley. It consists of the crystalline rocks of the Nawakot Complex, south of the Main Central Thrust. The Kuncha Formation (phyllite, schists and quartzites) of the Nawakot Complex is widely distributed in the area south of Syaphrubensi. This paper presents a preliminary study of the major challenges of road construction in the Trishuli river valley within the Rasuwa District. The alignment lies in the zone of highly weathered phyllites and schists covered by thick colluvial deposits with massive groundwater flow and steep slope of banded gneiss with dense discontinuities. The 2015 Gorkha earthquake with a moment magnitude of 7.8 induced widespread landslides and also changed the local geometry of slopes. Due to a close proximity to the Main Central Thrust, many shear zones and local faults are frequent in the river valley, which make the region more vulnerable to mass movements.

Assessment on failure of the road along BP Highway at Shitalpati, Sindhuli, Central Nepal

***Arun Dhoj Adhikari, Birat Shrestha, Nabin B. K., Roman Gantawa, Ranjan Kumar Dahal, and Suman Manandhar**

Central Department of Geology, Tribhuvan Univerysity, Kirtipur, Kathmandu
**Corresponding author: adhikariarundhoj@gmail.com*

A road section of BP Highway at Shitalpati of Sindhuli district collapsed in February 21, 2017 at 11 pm with the failure of retaining wall disrupting the vehicular movement. The repairing of damaged section was completed on June 30, 2017 with the construction of new retaining wall (Giri et al., 2017 and Bhatta, 2017). The cause of failure of the road section was assessed by determining the various properties of the backfill soil materials and also construction materials used in failed retaining wall. The index and strength parameters of collapsed backfill soil samples were determined as poorly graded sands (SP) and gravelly sands with fines (Howard, 1986). The laboratory shear box test provided the backfill has cohesion (c) and angle of internal friction (ϕ) as 0.014 kg/cm^2 and 41°, respectively. The specific gravity of soil was found to be 2.52 which determined the soil to be highly porous.

In the study area, construction materials are incorporated in the failed retaining wall as well in the newly constructed retaining wall. The study area consists of schist with quartz veins. The failed retaining wall consisted of monotonous slightly to moderately gneiss rock as the construction material Meanwhile the newly constructed retaining wall consist of quartzite, phyllite, metasandstone, gneiss and granite. Paralink is used to reinforce the retaining wall of the newly constructed retaining wall.

During April 2015 Gorkha Earthquake, the previously constructed retaining wall collapsed and highly influenced the road network. The poor quality of construction materials also assisted to make failure of retaining wall immediate after the shock. The failure of the road section was due to the porous backfill soil materials and weathered monotonous rock type. Therefore, it is very much important to consider these factors during construction of any road, for the long term stability and operation.

REFERENCES

Giri, S., Bhatta, T., and Karki, R. K., 2017, BP Highway obstructed as 37 Section Crumbles, The Kathmandu Post 21 February 2017.

Bhatta, T. P., 2017, Damaged Section of BP Highway repaired, The Kathmandu Post 30 June 2017.

Howard, K., 1986, Soil Classification Handbook: Unified Soil Classification System, Denver, Colo.: Geotechnical Branch, Division of Research and Laboratory Services, Engineering and Research Center, Bureau of Reclamation.

Journal of Nepal Geological Society, 2017, Vol. 54 (Sp. Issue)

Findings of geological, engineering geological and geophysical studies of the proposed Dotigad Hydropower Project Area of Dadeldhura District, Far Western Nepal

***Champak Babu Silwal[1], and Kabi Raj Paudyal[2]**

[1]*Central Campus of Technology, Dharan-14, Hattisar, Sunsari, Nepal*
[2]*Central Department of Geology, Tribhuvan University, Kirtipur, Kathmandu, Nepal*
**Corresponding author: geologistbabu@gmail.com*

Geological, engineering geological and subsurface investigation was carried out in the Bagarkot area, with the aim of site selection for the hydropower development from the Dotigad River. It is the Run-of-River (RoR) type project with the installed capacity of 5.78 MW. Study area lies in the Lesser Himalayan succession. Lithology of the area is divided into two units: the Schist Formation and the Gneiss Formation. Schist is distributed as finger like pattern within the gneiss mass. The proposed weir axis has well exposed bedrock on both banks. Proposed desander and powerhouse areas lie on the alluvium deposit of Dotigad. However, the area between the intake and powerhouse has mostly residual soil cover with about 200 m thick shear zone. The area of penstock alignment lies on the colluvium. Underground wedge stability analysis was carried using the orientation of joints along HRT with software Unwedge 3.0. It provides the information about safety factor, size, volume of wedges and its associated joints. The rock of the area has three plus random joint sets. The RMR and Q-value ranges from 68–57 and 24.4–9.266, respectively. The rock of the area is categorized as fair to good.

In subsurface study, 2D ERT survey was conducted to access the depth of bed rock and other sub-surface geological condition. The result was verified by the drilling method in the key project areas. Falling head field permeability test was conducted and the coefficient of permeability was found to lie between the ranges 1.25×10^{-5}–7.06×10^{-7} m/s indicating permeable to semipermeable. Analysis of geo-technical parameters of rock mass was done using the data from the field and their empirical relations. Average in-situ deformation modulus ranges between 33.51–19.09 Gpa. The in-situ horizontal and vertical stress ranges from 14.89–8.70 MPa and 8.22–2.08 MPa, respectively, where their ratio (k) ranges from 4.9–1.79. The Damage Index of the rock mass along HRT ranges from 0.19–0.11, which indicates that stress induced damage does not occur. Petrographic analysis of representative rock samples reveals that the rocks have enough bearing capacity as the rocks are fresh and free from adverse micro-cracks. The support design for the tunnel is suggested for the combination of local to systematic bolting and shotcrete. On the basis of overall study, the area is found to be feasible and suitable site in the context of folded and thrusted mountain belts of the Himalaya.

Assessing the proposed Khurkot-Manthali tunnel alignment along Sindhuli-Ramechhap Districts, Central Nepal

*** Harichandra Budhathoki, Pushp Raj Bhatta, Kabita Maharjan, Ajaya Chapagain, Shankar Pantha, Ranjan Kumar Dahal, and Suman Manandhar**

Central Department of Geology, Tribhuvan University, Kirtipur, Kathmandu, Nepal
**Corresponding author: geology.harichandra@gmail.com*

The mountainous country like Nepal faces many challenges in the development of transportation sector in Nepal. Slope instability, long and narrowed looped road networks are the major barrier to the development of nation and has been directly affecting to the economy of the country.

The traditional practice of constructing roads by means of cutting and filling of the slope are mostly vulnerable in terms of stability of road in hilly regions. Reliable solution to this problem could be overcome by aligning the road tunnel system in order to provide the shortest possible route to connect two regions that will help for the sustainable development of the locality.

In this reference, an engineering geological investigation for Khurkot-Manthali tunnel alignment (NE-SW) was carried out along Sindhuli District and Ramechhap District in Central Nepal. About 5.6 km of inverted v-shaped tunnel was proposed from Khurkot to Kunauri. The gradient of 0.5° of was maintained from both side of portal in order to manage proper drainage system. The center of tunnel was kept at about 2.8 km from both portal. The first portal was proposed at Sunkoshi Bridge, Khurkot in Sindhuli District while the second portal was proposed at Kunauri Bazar, on left bank of the Bhalu Khola in Ramechhap District.

Geologically, the proposed tunnel alignment lies in the Kuncha Formation of Lesser Himalaya. Major rock types are composed of phyllite, metasandstone and slate. The RMR tests throughout the section show fair to good condition. The region remains mostly dry except in rainy seasons. As a result, the overall engineering geological features strongly support for the alignment of proposed tunnel route in the region. Through this proposed tunnel alignment, around 40-45 minutes distance (by bus) of Khurkot to Manthali can be minimized nearly to 13 minutes.

Problems of control and reduction of inflow of water to road Ddeep-level tunnel, Russia, Moscow

***Kostikova I. A., Batrak G. I., Pozdnyakova I. A., Galitskaya I. V., and Toms L. S.**

[1]*ergeev Institute of Environmental Geoscience Russian Academy of Sciences (IEG RAS), Moscow, Russia*
**Corresponding author: kostikova@geoenv.ru*

In the last decade on the territory of the city of Moscow, a large number of road tunnels have been built. Since 2003, several road tunnels have been commissioned at a depth of about 30 m. The overall experience of their operation was successful. However, there are examples of the opposite situation.

Alabjano-Baltijskij tunnel was built from 2006 to 2016. In the result of errors of design, construction failed to achieve the acceptable parameters of waterproofing tunnel body. Considerable complexity in its use creates underground water seeping into the tunnel. In the winter, these leaks lead to ice accumulation on the road that can cause accidents.

The tunnel passes through a lithologically heterogeneous stratum, and is hydrodynamically the deepest drain, to which the flow of groundwater rushes from a large area of the entire water-saturated stratum, overlying the regional confining layer: Callovian-Oxford clay.

As a way of fight against water inflows the possibility of the organization of a drainage has been studied by the system of the vertical wells drilled from the tunnel bottom in his contour. However, the work of drainage will reduce the level of groundwater in an area of over 15 square km, which can cause precipitation of ground subsidence and the activation of exogenous processes. For making such decisions, it requires extensive hydrogeological study.

To solve this problem, a geo-filtration model was created. The main problem was an adequate reflection on the model of filtrational heterogeneity of water-bearing deposits in the aquifer, which significantly affect the simulation results of a vertical drainage.

Initially, on the basis of 1478 wells with a total depth 54078 m, a 3-D lithological model was formed. Since often interchangeable interlayers of different-grained sand, sandy loam and loam are not sustained in a section or in a plan, it was impossible to break the entire thickness into several homogeneous layers with characteristic filtration properties corresponding to the lithology of the water-bearing rocks (Fig. 1).

The problem was solved by dividing the thickness into 13 conventional layers, and calculating the filtration coefficient for each model block, taking into account the thickness and lithological composition of the prevailing geological material.

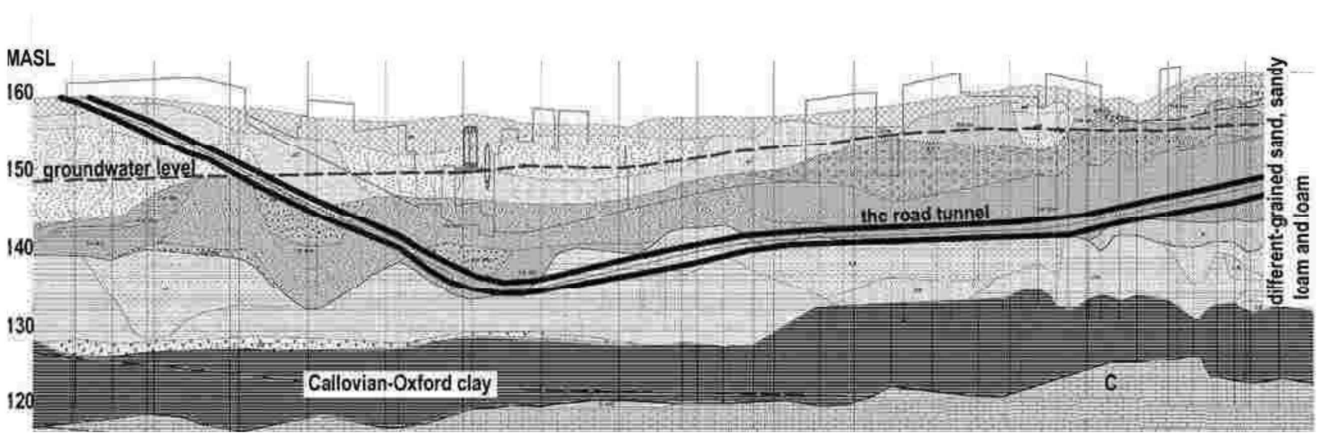


Fig. 1, Hydrogeological scheme

Sediment load and its source identification: a comparative study of Lake Phewa and Kulekhani reservoir, Nepal

***Prabha Neupane, Kumud Raj Kafle, Bed Mani Dahal, Chhatra Mani Sharma, Nani Raut, Smriti Gurung, Babi Kumuar Kafle, and Sushma Manandhar**

Department of Environment Science and Engineering, Kathmandu University, Nepal
**Corresponding author: neupane.prabha@gmail.com*

Sedimentation has been threatening the sustainability and also compromising the ecosystem functions of lakes and reservoirs. Sediment studies have been carried out extensively in water resources of Nepal especially in correlation with the hydropower projects, and Lake Phewa and Kulekhani Reservoir have been a prime candidate site. This study aims to identify and compare the sources of sediments to account for the suspended sediment load of Kulekhani Reservoir and Lake Phewa through field and laboratory analysis and Remote Sensing. Field work consisted of turbidity, discharge measurement and suspended sediment sampling which was later analysed in the laboratory. Land cover map was prepared from satellite images obtained from Landsat TM L8, OLI/TIRS to classify the observed bio - physical cover of the study area to account for the suspended sediment load of the lake and reservoir. The annual sediment load from Phewa watershed is estimated to be 7.60 tonnes per annum with the largest contribution from Harpan Khola and from Kulekhani Watershed is 4.53 tonnes per annum with the largest contribution from Palung Khola. Land cover maps of the study areas exhibit that agricultural area covers the significant portion of both the watersheds. Excessive tillage thus facilitates increased surface runoff from these areas and consequently high suspended sediment load. However, the use of derivatives such as MIP method for discharge calculation can be highly erogenous. Hence, a continuous and comprehensive assessment of sedimentation is required for accurate estimation of sediment load along with implementation of agricultural best management practices and land conservation techniques to sustain aquatic ecosystem.

Journal of Nepal Geological Society, 2017, Vol. 54 (Sp. Issue)

The world's southernmost geotechnical investigation, Ross Island, Antarctica

***Sophie Bainbridge, and Tim McMorran**

Golder Associates (NZ) Ltd., Level 1, 214 Durham Street, Christchurch, New Zealand
**Corresponding author: sbainbridge@golder.co.nz*

Antarctica is an extraordinary continent. Most of the land mass is permanently covered in ice, and Antarctica can "double in size" in winter due to thick ice sheets that grow out from the shoreline. Ross Island, within the Ross Sea, is home to the largest Antarctic research base, McMurdo Station, which is operated by the National Science Foundation (NSF) and United States Antarctic Program (USAP) as well as Scott Base, which is considerably smaller and operated by Antarctica New Zealand (Fig. 1).

The extremely harsh climate at Ross Island presents many challenges to constructing safe and energy efficient buildings, suitable as major research bases. Current infrastructure at both bases has become old and inefficient and it is proposed to update both bases in order to reduce the environmental impact and provide functional and workable spaces with the key objective of enhancing the science that is conducted in Antarctica and the Southern Ocean.

Golder was contracted to undertake a geotechnical investigation and provide advice on managing permafrost effects, the importance of climate change on foundation performance, anchor design, blasting of rock, seismic hazard and most importantly, minimizing the environmental impact of any activity on site.

The first obstacle was designing and implementing a comprehensive geotechnical investigation in one of the harshest environments on the planet. An environmentally friendly cooled compressed air flushed coring method was used to recover core samples from the ground that were logged and sampled. Steel bars were then installed in some of the holes using different grout combinations and pulled out to test their strength for future ground anchors beneath the foundations. Several holes were instrumented with thermistors that will read temperature changes in the ground throughout the year. This understanding of ground temperature variation will allow buildings to be founded beneath the freeze-thaw zone and for future proofing against climate change.

Despite the challenges of working in such harsh environments the geotechnical investigation successfully collected high quality information and developed a comprehensive model of the ground conditions beneath McMurdo Station and Scott Base.

Fig. 1, McMurdo Station and observation hill, Ross Island, Antarctica

Bifurcation theory for geomechanics

***Sunjay Manas Banerjee[1], and Hari Ghimire[2]**

[1]*Department of Geophysics, BHU, Varanasi-221005, India*
[2]*Explorer Geophysical Consultants Pvt. Ltd, Nepal*
**Corresponding author: sunjay_sunjay@hotmail.com*

Bifurcation theory is the mathematical study of changes in the qualitative or topological structure of a given family, such as the integral curves of a family of vector fields, and the solutions of a family of differential equations. Most commonly applied to the mathematical study of dynamical system, a bifurcation occurs when a small smooth change made to the parameter values (the bifurcation parameters) of a system causes a sudden 'qualitative' or topological change in its behavior. Bifurcations occur in both continuous systems ordinary differential equation (ODE), delay differential equations (DDEs) or partial differential equation (PDE) and discrete systems (described by maps).

The word bifurcation refers to the loss of uniqueness of the solutions of a given boundary problem. These notions of stability and bifurcation thus refer to a mechanical system with well-defined boundary and initial conditions. For engineering applications, stability and bifurcation analyses usually involve a finite domain subjected to non-homogeneous stress and strain states. By applying the bifurcation theory of solid mechanics, the bifurcation behavior of rock due to the change of rheological parameters after the deformation turning into the accelerating creep phase is studied, the rheological parameters, which cause the creep bifurcation behavior of rock, are determined and the bifurcation points are obtained. Failure of geomaterials is characterized by the formation and propagation of zones of localized shear deformation. The localization process is seen as an instability that can be predicted from the pre-failure constitutive behavior of the material Bifurcation: Loss of uniqueness of a given boundary value problem (no reference to a perturbation). These notions of stability and bifurcation thus refer to a mechanical system with well-defined boundary and initial conditions. Material instability, the mechanical system is a material element (Representative Elementary Volume in a homogeneous state of stress and strain). Spontaneous change of the deformation mode in the next loading increment is seen as a material instability (bifurcation state).The strain localization analysis consists in searching the incipient of a shear band in a solid as a mathematical bifurcation condition for the deformation field. The strain localization phenomenon is understood as the appearance of a discontinuity in strain rates which marks the onset of non-uniform response. Localization is favored when the pre-bifurcation, homogeneous field contains a plane of zero extension rates, as in plane strain whereas highly destabilizing effects as strong softening behavior is needed to generate shear band formation in axisymmetric deformation. Discontinuous bifurcation: elastic unloading occurs outside the band while continued elastic-plastic loading occurs within the band. Continuous bifurcation: The constitutive tensor is continuous across the band. Aniso Viscoelastic (salt) rock properties study is challenging task. Wavelet analysis of break out in geomechanics is essential.

Journal of Nepal Geological Society, 2017, Vol. 54 (Sp. Issue)

Pipeline rupture and post-construction geohazards assessment of pipeline route over mountainous region in East Malaysia

Abd Rasid Jaapar

Geomapping Technology Sdn Bhd, Bandar Baru Bangi, Selangor, Malaysia
E-mail: arjaapar@geomappingtechnology.com

Trans-states gas pipeline was constructed from the state of Sabah to Sarawak of East Malaysia. Prior to gas in, the test pressure was performed. Two days later, the gas pipeline ruptured and exploded near a small town of Lawas. Several investigation teams were sent to identified the root cause of the incident. During the incident in June 2014, the explosion had caused ground shaking and substantial displacement of soils around the incident location which led to additional soil disturbance. The fire associated with the explosion also burnt off an extensive area of vegetation which again further promoted surface water infiltration over a large area of the site. The soil surrounding the ruptured location was weaker when compared to that before the incident. It is anticipated that ground movement would continue for a period of time after the explosion. Although the ground movement may diminish, the ground movement would still continue in particular during monsoon seasons.

The site was mainly covered with a layer of colluvium which comprises heterogeneous transported soil with variable particle grain size composition, from fine grains to over 300 mm in size. It consists of sub-angular to sub-rounded boulders, silty clay and gravels. The Setap Shale, which is also found in Beliat, Miri and Liang Formations, is described as a thick monotonous succession of shale with subordinate sandstone and a few thin lenses of limestone. It is generally dark grey to black in color.

Geohazards assessment at several other locations showed that there were many cases of the pipeline exposed due to erosion and scouring process caused by the uncontrolled storm runoff from the surrounding areas. The natural terrain were cut massively and changed without regard to the natural hydrological catchment boundary and its regime. Many locations along the pipeline remained exposed to the elements of weather. Many of the steep slopes would require further assessment and analyses into the stability of slopes. More works are necessary to gather the relevant information for analyses and evaluation of long terms solutions to ensure the integrity of the pipeline. Several recommendations based on risks management concept were proposed and presented in this paper.

Assessment of debris flow deposits around Palung Valley, Makwanpur district

***Arishma Gadtaula, Rabina Hada, and Pushkar Bhandary**

Department of Geology, Tri-Chandra Multiple Campus
**Corresponding author: arish123gadtaula@gmail.com*

The Palung valley, Central Nepal experienced prodigious debris flow deposits following a continuous rainfall lasting 19-21 July, 1993 (Dhital et al., 2014). This notorious disaster claimed the loss of lives and property along with severe damage to the infrastructures including roads, bridges, and blockage of the Kulekhani dam. Cloudburst was the prime triggering factor resulting in debris flow followed by orographic precipitation, topography and geology (Dhital et al. 2014). The debris deposits of weak, weathered Palung granite swept away many houses, people, and cultivated land at Phedigaun, and at Kiteni Khola section. The debris flow events along Kiteni Khola section and Phedigaun were studied as they contributed to the flood event in 1993. Phedigaun is located at an altitude of approximately 1,800 m in the upper reaches of the Kulekhani watershed (Dhital et al., 2014).The Kiteni Khola was also severely affected by debris flow. The parameters involved during the debris flow assessment included location, dimensional and attribute properties of the observed debris fan deposits. The attribute properties further emphasized on geological, geomorphological and social aspects. The cross-sectional views of the debris deposits were prepared considering the dimensional properties of the studied area which further assists in assessment of the debris flow deposits. The longitudinal profile prepared along Kiteni Khola concluded severe sediment deposition including granite boulders of 1-10 m. Steep slope, source of abundant debris supply i.e. Palung granite and the orographic precipitation contributes to the slope instability leading to debris flow problems in Palung valley.

REFERENCES

Dhital, M.R., Manandhar, S., Rakenori, H., and Daisuke, S., 2014, Sediment accumulation in the Kulekhani reservoir due to the 1993 debris flows and landslides. 9th International Symposium on Lowland Technology, Japan, pp. 443-450.

Slope failure assessment by kinematic analysis in Kulekhani Watershed

***Badal Pokharel, Shila Bhattarai, Krishna Pudasaini , and Prem Bahadur Thapa**

Department of Geology, Tri-Chandra Multiple Campus
**Corresponding author; badal.pokharel2@gmail.com*

The study area lies in Kulekhani watershed and the area comprises of meta-sandstone, phyllite, schist, quartzite and marble. Most of the slopes in Kulekhani watershed are in steeper topography and many slope failures were happened in past decades. The debris flows and landslides are observed mostly on the steep upper reaches of the Kulekhani watershed (Dhital et al. 2014). Many large plane rockslides occurred on the slopes west of Phedigaun where the hill slope angle ranges from 30º to 40º (Dhital et al., 2014).

Kinematic analysis of the slopes is carried out at seventeen different spots of the study area by stereographic projection in-order to interpret the condition of rock slope instability. At each spot seventy data for orientation of rock discontinuities is taken. The analysis at Palung-Kulekhani area indicated that the possibility of toppling failure is high in phyllites of Kulikhani Formation whereas wedge failure seems to be prominent in marble beds of Markhu Formation. Plane failure possibility is found to be present in Kulikhani Formation and Markhu Formation as well.

The slopes with dip angle between 30º-65º have undergone many of the failures and even further chance of failures is high in these slopes. The haphazard excavation is one of the major reasons for unstable slopes along highway. Other reasons are intense rainfall and differential weathering (phyllite and quartzite in Kulikhani Formation).

REFERENCES

Dhital, M.R., Manandhar, S., Rakenori, H., and Daisuke, S., 2014, Sediment accumulation in the Kulekhani reservoir due to the 1993 debris flows and landslides. 9th International Symposium on Lowland Technology, Japan, pp. 443–450.

Depth susceptible to the internal erosion on the basis of grain size analysis of the sediment deposited along the sinkhole affected Armala area, Kaski District Nepal

***Basant Bhandari, Jivan Bhusal, Ramamohan Pokharel, and Lalu Paudel**

Central Department of Geology, Tribhuvan University, Kirtipur, Kathmandu, Nepal
**Corresponding author: basantgeo@gmail.com*

Armala valley of Kaski district of Nepal is experiencing sinkhole problem since 2013. Cultivated land along with sparse settlement on the right bank of the Kali Khola attracted attention of several researchers after the event, which is still ongoing.

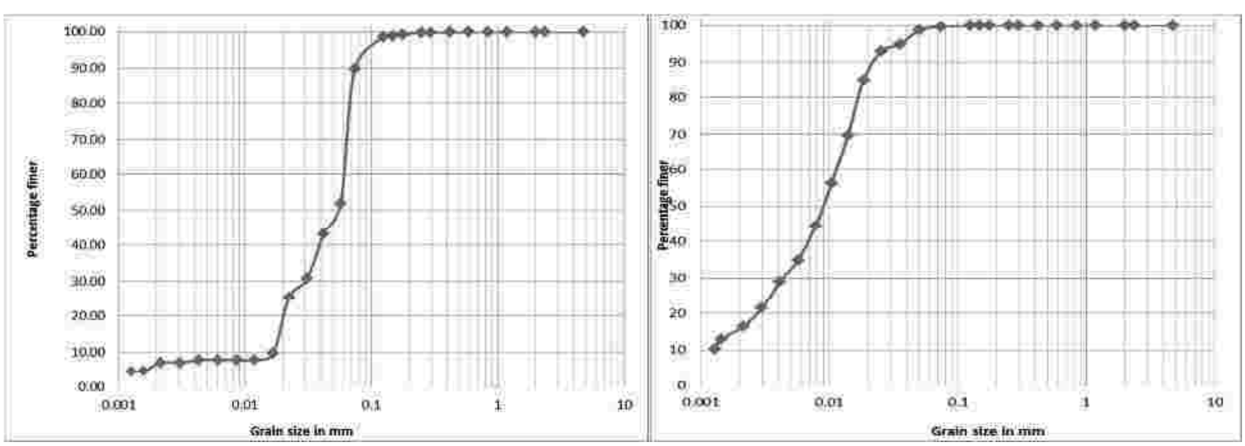
A vast volume of gravels were transported by the Seti Khola from the Annapurna Range to fill up the Pokhara Valley (Yamanaka *et al*. 1982). But instead of the gravel from the Annpaurna Range, the Armala sub-basin of the Pokhara valley is filled up with calcareous clayey silt, which is undergoing internal erosion due to flow of subsurface water and formation of subsurface caves and ultimate formation of sink holes.

Present study is concern about the depth of origin of internal erosion along the sinkhole affected Armala area on the basis of the grain size analysis of the layered clayey silt deposit along the area (Fig. 1).

To obtain the objective, grain size analysis of each visually distinguished layer form the river cut section along the study area has been done using the sieve analysis as well as hydrometer analysis and exact proportion of sand silt and clay is figured out. Interestingly the layer at the depth of 2.75m from the surface at the sample location has shown relatively highest hydraulic conductivity and the layer just beneath it has relatively lowest hydraulic conductivity. So the contact between these two layers of clayey silt deposit has been considered as the most susceptible depth for the internal erosion along the Armala valley for the formation of subsurface caves and ultimate sinkholes.

REFERENCES

Yamanaka, H., Yoshida, M. and Arita, K., (1982), "Terrace landform and Quaternary deposits around Pokhara valley, Central Nepal." Journal of Nepal Geological Society, 2, 95-112.



(a) (b)

Fig. 1, (a) Grain size distrubution curve of the sediment most susceptible to the internal erosion with high hydraulic conductivity, and (b) Grain size distribution curve of the sediment just below (a) with low hydraulic conductivity

Stabilization measures of stream planform in the Siwalik Hills of Nepal – evaluation results of a pilot project

***Daisuke Higaki[1], Naoto Koiwa[2], Mio Takahashi[2], Sohan Kumar Ghimire[3], Tara Bhattarai[4] and Kishor Kumar Karki[4]**

[1]*Faculty of Agriculture and Life Science, Hirosaki University, Bunkyocho, Hirosaki, Japan*
[2]*Faculty of Education, Hirosaki University, Bunkyocho, Hirosaki, Japan*
[3]*UK Flood Risk, 18 St Nicholas Road, London SE18 1HJ*
[4]*Kathmandu, Nepal*
**Corresponding author: dhigaki@hirosaki-u.ac.jp*

The Siwalik Hills known as the foothills of the Himalayas, are geologically young with active crustal movement and characterized by steep slopes and highly dissected terrain where soil erosion, mass movement processes are very active. Such geo-environmental processes combined with monsoon rainfall result in river channel shifting with bank erosion and sedimentation in the downstream reaches. This paper presents the results of an evaluation of a pilot project on the effectiveness of river course stabilization in the Khajuri stream catchment, a tributary of Trijuga River in the Siwalik Hills, eastern Nepal.

The Khajuri stream catchment has an area of 5.8 km^2 with the elevation ranging from 165 m to 410 m in the hills. The mitigation measures adopted in the downstream area by the JICA/Government of Nepal Water Induced Disaster Prevention Technical Center Project (DPTC) in 1997-1998 included earthen embankment and revetment along with series of gabion spurs and tree plantation on the floodplain (DPTC, 1999; Fig.1). The width of the stream and the height of embankment were designed as 60m, same as the natural width in 1996 and 1.3m respectively. The planted trees were aimed to develop into a forest which would reduce the flood energy in case of overtopping.

The evaluation survey was conducted in the lower and middle reach of the Khajuri stream in 2002 and 2013-2016. Even though the middle reach of the stream had partially expanded, more than 10 m wide by bank erosion, the embankment in the downstream reach have sustained at both banks with minor collapses of revetment. Whereas the riverbed level has aggraded less than 1m at the lowermost embankment section, it has not changed at other embankment sections. Series of spurs were found effective for sedimentation which also protected the embankment from scouring erosion at the uppermost embankment section. However, the planted trees behind the left bank such as *Daivergia sisso and Acacia catechu* which had sustained more than four years almost disappeared before 2013.

The planform of Siwalik streams is unstable because of extremely erodible fine bank materials of molasses origin (Higaki, 1999). The river training works using the earthen embankment and gabion revetment were found effective for stabilizing the channel banks and the river bed. The riverbed aggradation in the lowermost reach due to the narrow causeway disappeared after bridge construction in 2012. Failure of tree plantation was due to deforestation due to the lack of watchman after the project.

REFERENCES

DPTC, 1999, Final report on Udaypur model site, Water Induced Disaster Prevention Technical Centre, 41p.

Higaki, D., 1999, Erosion and sedimentation problems in Nepal from the viewpoint of morphological development. Journal of Nepal Geological Society, 18, 309-318.

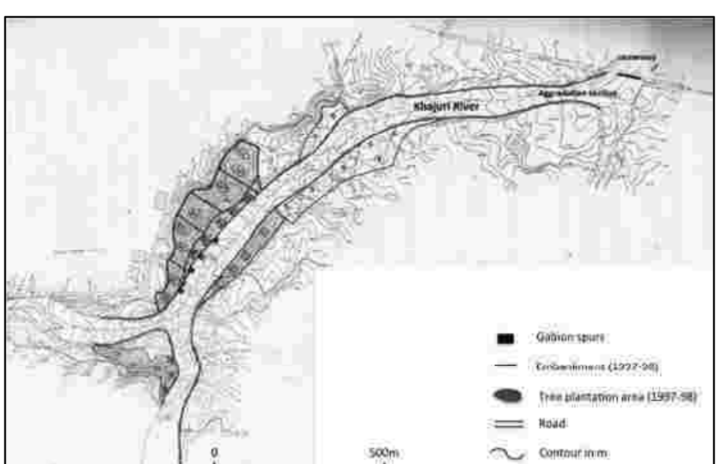


Fig. 1, Adopted Mitigation Measures in the Khajuri Watershed（modified from DPTC, 1999 ）

Geological investigation of karst terrain and geophysical detection of underground cavities in the Kusma-Baglung area, west Nepal

***L. P. Paudel[1], S. Lamsal[1], K. P. Subedi[2], Nabaraj Sapkota[1], Arjun Bhandari[1], Ishor Gyanwali[1], U. C. Bhusal[1,3], S. Rajaure[4], K. R. Paudyal[1], and B. R. Adhakari[2]**

[1]*Central Department of Geology, Tribhuvan University, Kirtipur, Kathmandu, Nepal*
[2]*Department of Civil Engineering, Pulchowk Campus, Tribhuvan University, Lalitpur, Nepal*
[3]*Explorer Geophysical Consultant Pvt. Ltd, Banasthali, Kathmandu*
[4]*Department of Mines and Geology, Lainchour, Kathmandu, Nepal*
**Corresponding author: lalupaudel67@yahoo.com*

Karst is a very difficult ground conditions from engineering point of view. Differential compaction and settling, subsurface erosion (piping), collapse of ground and underground drainage etc. create a number of engineering and environmental problems. The problem is more severe if it is in urban area.

The Modi Khola and Kali Gandaki valleys in the Kusma-Baglung area of west Nepal, Lesser Himalaya are characterized by a number of spectacular river terraces. These terraces show extensively developed karst geomorphology with a number of karstic features including underground caves, tunnels and cavities. These karstic features have posed risk of sinkhole and subsidence to the fast-growing cities like Kusma and Baglung. In the present study, an attempt was made to investigate the karst terrane in the Kusma-Baglung area using geological and geophysical methods.

The river terraces along the Modi Khola and Kali Gandaki valleys were mapped at 1:25,000 scale and their lithological and sedimentological characteristics were investigated. Investigation shows that the river terraces of the Modi Khola and Kali Gandaki show different lithofacies characterstics. The terraces of Kali Gandaki are mostly of fluvial origin with clast-supported well-rounded boulders, cobbles and gravels cemented with calcite. In contrary, the river terraces of the Modi Khola area show debris flow characteristics with angular boulders, cobbles and gravels supported by muddy matrix. They are also well cemented by calcite. Spectacular karst features such as sinkholes, karst valleys, caves, spleotherms, karren and pinnacle rockheads are developed in the terraces. These features are the result of the dissolution of calcareous cement and carbonate clasts in the conglomerate. Sinkhole formation is a major geo-hazard in the area posing threat to the buildings, roads and agricultural lands.

Two-dimensional (2D) Electrical Resistivity Tomography (ERT) and Ground Penetrating Radar (GPR) survey was carried out in the present study in order to locate the subsurface karstic features such as voids or cavities. The study demonstrates that the ERT survey can be effectively applied to reflect and differentiate superficial soil, clay, weathered rocks, compact of intact rocks, and air filled karstic features. The GPR method was also found to be an effective technique for the identification of subsurface features.

It is recommended to carry out further detailed geological and geophysical study of the area for sustainable urban planning.

From seismic hazard assessment to seismic risk prevention in the island of Hispaniola

Myriam Belvaux[1], Didier Bertil[1], Monique Terrier[1], Nicolas Taillefer[1], and *Jean-Philippe Rançon[2]

[1]*Risks and Prevention Division, BRGM, Orléans, France*
[2]*International Division, BRGM, Orléans, France*
**Corresponding author: jp.rancon@brgm.fr*

Shared by Haiti and the Dominican Republic, the island of Hispaniola is a strongly active seismic zone, at the boundary between the North American and Caribbean plates. The Mw 7.1 earthquake on January 10, 2010, which destroyed the capital of Haiti, Port-au-Prince, was a reminder with regard to the exposure of Hispaniola to severe seismic hazard. BRGM, the French Geological Survey, is actively involved in numerous complementary studies aiming to improve assessment and prevention of natural risks at different scales.

Through an updating knowledge on the potentially active faults of the northern Caribbean, a seismotectonic synthesis covering Hispaniola and its margins was carried out. A unified catalog of earthquakes was established, from the collection of historical and instrumental data. The resulting seismic zonation was applied to assess the regional seismic hazard for Santo Domingo. At a local scale, a study of the tectonic setting of the Port-au-Prince metropolitan area led to new maps of active faults and geological structures (Terrier et al., 2014).

Between 2011 and 2016, programs of seismic microzonation were launched for seven cities in Hispaniola including the two capitals, Port-au-Prince and Santo Domingo. The aim was to identify areas where lithological/topographical site effects can be significant, and areas where liquefaction or landslides can occur.

Inappropriate building techniques and poor urban planning increase the risk level. Seismic vulnerability of residential buildings was studied in the Santo Domingo urban area. Several risk scenarios were then developed to estimate the potential damage caused by earthquakes to a selection of infrastructures. This expertise has been scaled down through vulnerability diagnostic of strategic buildings, including Haitian secondary schools to recommend solutions in terms of seismic reinforcement and to reduce their vulnerability.

Other significant examples of BRGM's contributions in Haiti are a national atlas of natural hazards and two Urban Risk Reduction Plans. Moreover, BRGM put forward a major component on preventive measures and communication tools to the public, the authorities, etc. as well as skills transfers, particularly to young geologists and engineers of the national institutions.

REFERENCES

Terrier M., Bialkowski A., Nachbaur A., Prépetit C., & Joseph Y.-F. (2014). Revision of the geological context of the Port-au-Prince metropolitan area, Haiti: Implications for slope failures and seismic hazard assessment. Natural Hazards and Earth System Sciences, v. 14(9), pp. 2577–2587.

BRGM/CIAT/World Bank (2017). Atlas des menaces naturelles en Haïti. Bibliothèque Nationale d'Haïti. ISBN 978-99970-4-871-4.

Characteristics of landslides in Nepal and their hazard evaluation

Prem Bahadur Thapa

Department of Geology, Tri-Chandra Multiple Campus, Tribhuvan University, Kathmandu, Nepal
Email: geoscithapa@yahoo.com

Different types of landslides are occurring in Nepal due to intricate topography, diverse geology, and extreme events. Triggering factors such as rainfall and earthquakes play vital role to cause the mountainous terrains vulnerable to landslides and other mass wasting processes. The combination of varied geology and monsoon season makes each physiographic zone of Nepal unique in their characteristics of landslides. Landslides are spatially localized in steep slopes of river valleys, close proximity to thrust faults or boundary between competent and incompetent rock strata. Dip-slope conditions of major discontinuities are the main cause of landslides when excavations are made into dip-slopes or slopes with upward inclined strata, potential planes of weakness are exposed i.e. often encounter such daylight situations due to geological complexities (e.g. faulted/folded rock strata geometry). Many landslides in mountain hill-slopes are originating as planar slides at initiation and converted into debris slide to flow which generally moves in down-slope with high velocity. Foliations dipping back into slope or vertically stratified strata often undergo massive toppling failures and intersections of joints lead to wedge failures. Field evidence and data analysis shows that landslides in Nepal Himalaya are because of the complex interplay of various factors (lithology, geological structures, slope morphometry, rainfall or earthquake etc.) which are crucial for the hazard evaluation.

Professionals from government and non-government departments, international organizations, and researchers from academic institutions carry out the landslide hazard evaluation in Nepal. The area of investigation and methodology applied by those individuals differs considerably i.e. majority of these activities focus on local scale of particular interest and a systematic method of landslide hazard evaluation has not implemented pragmatically to deal with the landslide susceptibility/hazard that have resulted the increasing number of landslides in the mountain hill-slope especially evident in recently expanding rural roads or widening of major highways. Judgment on various methods of landslide hazard assessment in Nepal have revealed that evaluation methods range from subjective rating of heuristic approach to the semi-quantitative (bivariate) and quantitative (multivariate and deterministic) approaches. Due to the large spatial variability of the mechanical, hydrological, and geometrical parameters in different geo-environmental settings, the application of deterministic approach is not frequent as it requires detailed geotechnical data. Therefore, the statistical modeling is more common practice for landslide hazard evaluation.

Development of generalized regression model for soil depth to bedrock in an anthropogenic landscape–a case study of Phewa Watershed in Panchase region of Central-Western Hills of Nepal

***Sanjaya Devkota[1], Narendra Man Shakya[1], Karen Sudmeier[2], and Brain Mcadoo[3]**

[1] *Department of Civil Engineering, Institute of Engineering, Tribhuvan University, Nepal*
[2]*Institute of Earth Science, University of Lausanne, Lausane, Switzerland*
[3]*Yale-NSU College, Singapore*
[*]*Corresponding Author: devkotasanjaya@gmail.com*

Soil Depth to Bedrock (SDtB) is highly variable and important input parameter for soil surface modeling including various types of mass movement, which is most often, ignores its variability. In an anthropogenic landscape SDtB does not necessarily depends on natural processes, making it difficult to apply physically-based approach. This study explored the possibility of using topographic attributes to model the SDtB in a complex topography of Phewa Watershed in Panchase region of Nepal. SDtB of 865 points were surveyed along the excavated cut slope of rural road network of about 300 km built in various time periods in the past within the watershed (117 sqkm). The surveyed SDtB point data were divided into calibration (80%) and test (20%) data sets. Topographic attributes (e. g. slope, curvature, altitude, compound terrain index, etc) were derived from the Digital Terrain Model followed by land cover attributes from Landsat remote sensing images. A multiple linear regression model was developed to predict SDtB over the watershed utilizing the attributes. The model was able to explain about 65% of the spatial variability of SDtB indicating that it is useful to predict the soil depth in a complex topography of Panchase mountains region of Nepal.

REFERENCES

Devkota, S., Sekhar, L. K., & Jetten, V. G., 2008, Prediction of soil depth using topographical variables for debris flow initiation modeling in the upper Tikovil River basin, Kerala, India. EGU 2008.

Tesfa, T. K., Tarboton, D. G., Chandler, D. G., and McNamara, J. P., 2009, Modeling soil depth from topographic and land cover attributes, Water Resour. Res., 45, W10438, doi: 1029/2008WR007474

Flood hazard analysis along Bhusghat Khola, Gharti Khola and Shankhamul Khola in Palung Valley, Makwanpur District, Nepal

***Sharmila Neupane, Sanjeeta Pandit, Bhuvan Panday, and Prem Bahadur Thapa**

Department of Geology, Tri-Chandra Multiple Campus
**Corresponding author: prospicuous.sharu1@gmail.co*

Flood hazard occurs frequently due to intense precipitation, especially during monsoon. Historical review of flood events in the study area, Palung Valley, showed excessive flooding in July 1993 resulting in deaths, inundation, washing out of houses and large sediment deposition obstructing the Kulekhani Reservoir (Dhital et al., 1993). Therefore, this field study was carried out to observe the land use condition and flood protection measures at present along the Bhusghat Khola, Gharti Khola and Shankhamul Khola in the Palung Valley for flood hazard analysis. The flood hazard analysis along these rivers was entirely based on the geomorphologic and field evidences. Several river cross-profiles were made. Considerable settlement was observed along the floodplain and it was observed to be intensively used for agriculture. Sediment deposition along these rivers was quite large with evidences of erosion at the banks increasing the probability of flooding even during moderate rainfall. Though structural measures for flood protection such as construction of spurs, dykes and embankments were observed in some sections along these rivers possible failures of these flood protection measures and inundation within those areas needs to be evaluated. Through such field evidences, land use pattern and interaction with the local people on past flooding levels it was concluded that the settlement around the floodplain is in potential risk for future flood events. Use of early warning system, expanded monitoring of floods and construction of flood protection structures are highly recommended in the area to reduce the risk.

REFERENCES

Dhital, M. J., Khanal, N. and Thapa, K. B., 1993, The Role of Extreme Weather Events, Mass Movements and Land Use Changes in Increasing Natural Hazards, International Centre for Integrated Mountain Development, Kathmandu, Nepal, 123 p.

Study on gross streambank sediment erosion from the Godavari Khola, southeast Kathmandu Valley, Central Nepal

***Ujwal Kumar Maskey[1] and Naresh Kazi Tamrakar[2]**

[1]*Total Earthscience Consult and Research Pvt. Ltd., Shantinagar, Kathmandu, Nepal*
[2]*Central Department of Geology, Tribhuvan University, Kirtipur, Kathmandu, Nepal*
**Corresponding author: theujwalmaskey@gmail.com*

The fifth order Godavari Khola is flowing from the South to the North direction and is one of the major tributaries from the southern part of the Kathmandu Valley. As the urbanization is growing in the Kathmandu Valley the banks of the streams are being targeted for the housing and roads, therefore it is important to know the characteristic of the river behavior, nature of erosion and sediment production along its banks. This study accesses the stream bank erosion characteristics and sediment production by erosion along the Godavari Khola. It was conducted by surveying and accessing hydraulic parameters, Bank Erosion and Lateral Instability status, streambank recession rates and gross sediment erosion from the bank.

The Godavari Khola has high bank erodibility and lateral instability as the hazard level of Bank Erosion and Lateral Instability (BELI) and W/D ratio are quite high. Since the slope and the bankfull depth exceed the critical slope and critical depth values, respectively, the Godavari Khola is competent enough to mobilize its sediments. The apparent recession rate of the banks of the Godavari Khola is 0.66 m per year yielding 85 m^3 volume of the displaced material which weighs 141 tons. The estimated bank erosion rate is in between 0.02 to 0.235 m/y and the gross erosion is estimated to be 320 tonnes per year. Similar to the other river of the Kathmandu Valley, the Godavari Khola is very disturbed by the anthropogenic activities. Riparian vegetation clearing and bad agricultural practice is one of the major causes for the high bank erosion and instability of the Godavari Khola.

Geohazard vulnerability scenario of megacity Dhaka, capital of Bangladesh

Maliha Malek[1], and *A. S. M. Woobaidullah[2]

[1]*Department of Disaster Science & Management, Dhaka University, Dhaka 100*
[2]*Department of Geology, Dhaka University, Dhaka 100*
** Corresponding author: woobaid.du@gmail.com*

Dhaka, the capital of Bangladesh is situated at the centre of the biggest delta plain and one of the fastest expanding cities of the country.

Physiographically, Dhaka is situated in the southern tip of Madhupur Tract and Floodplain area and is surrounded by Tongi Khal in the north, the Buriganga River in the south south-west, the Balu River in the east and Turag River in the west. The subsurface of the area is characterized by an unconsolidated sequence of fluvio-deltaic deposits of many hundreds of meters usually composed of gravels, sands, silts, and clays of Plio-Pleistocene age.

Recent studies based on GPS monitors observed that the north-eastern corner of the Indian subcontinent is actively colliding with Asia and Bangladesh is actually sitting on a huge subduction zone, potentially posing a major earthquake risk to the region. By filling swampy zones, settlements are sprawling at the periphery. Former Dhaka City Corporation (DCC) was dissolved by the Local Government (City Corporation) Amendment Bill 2011 and divided into two parts as Dhaka South City Corporation (DSCC) and Dhaka North City Corporation (DNCC).

Due to lithological variation and immense withdrawal of ground water, this city is at risk for any geo-hazard. Among them DNCC seems more vulnerable for geo-hazards like land subsidence, ground shaking, ground rupture and liquefaction. From the perspective of ground water depletion, depressions have been observed at some areas of DNCC like Mirpur, Tejgaon and Gulshan. From the perspective of geotechnical investigation, it has been observed that some areas of DNCC like Badda, Rampura, Notun Bazar show lower SPT with low AVS30. Such area show highest ground amplification by running model from PS log, SPT value and AVS30 data. Moreover, by cross-checking the vulnerable zones in the drainage map of Dhaka city of 1955, it is also found that those areas were traversed by numerous khal, streams and lakes. Considering all aspects, it can be said that DNCC seems more vulnerable for geohazard in Dhaka city.

Journal of Nepal Geological Society, 2017, Vol. 54 (Sp. Issue)

Rock fall hazard mapping in Siddhababa area of Siddhartha Highway, western Nepal

***Chhabilal Pokhrel, Ishwor Adhikari, and Ranjan Kumar Dahal**

Central Department of Geology, Tribhuvan University, Kirtipur, Kathmandu, Nepal
**Corresponding author: pchhabilal46@gmail.com*

Siddhababa rock fall area lies at the latitude 27º4318.17" N to 27̊4425.21̍ N and longitude 83̊2816.94̍ E to 83̊2800.32̍ E in the Palpa District, Western Nepal. Geographically, it lies in the Sub-Himalaya Zone (Siwaliks) also called Churia in Nepal, which is bounded to the south by Himalaya Frontal Thrust (HFT) and to the north by the Main Boundary Thrust (MBT) and extends entire length of the Nepal. The Siwalik Range is made up of sedimentary rocks such as mudstone, shale, sandstone, siltstone and conglomerate (Tokuoka et al., 1990). These rocks are very soft and can be easily disintegrated in to another form in short period of time. Lower and Middle Siwaliks rocks are more problematic due to presence of alternating beds of mudstone and sandstone. The properties of mudstone are to dissolve in water and saturated then flow easily and sandstone cannot easily dissolve in water which results overhanging of hard sandstone. If the mudstone beds go away then automatically sandstone disintegrates into blocks. The Upper Siwaliks contains thick beds of conglomerate which are loose in nature. Siwalik rocks are young and highly susceptible for landslide process during monsoon season.

The present study aims to investigate and understand the causes of rock fall and landslide and to prepare the final geological hazard map and to protect life of the passenger, properties and manmade structures and awareness for people. The parameters used for hazard map preparation based on Rock Classification:- Rock Quality Designation, Rock Mass Rating, Geological Strength Index and Slope Mass Rating and based on dips6 software kinematic analysis of rocks were done and parameters such as Planar Sliding, Planar Sliding no limit, wedge Sliding, Flexural Toppling and direct Toppling were also considered. Each parameter during the preparation of the hazard maps was prepared first and final hazard map prepared based on combining of the all parameters and topographic mosaic in ilwis3.3 software. The five categories such as very low hazard, low hazard, moderate hazard, high hazard and very high hazard have been considered during the preparation of the hazard map (Fig. 1).

The entire area was divided into 23 zones; each has 100m length. The zone no. 5 (Ch. 0+400 to 0+500) is said to be very low hazard; the zone no. 8 and 9 (Ch. 0+700 to 0+900) and zone no. 16 and 17 (Ch. 1+500 to 1+700) are said to be low hazard; the zone nos. 1 to 4 (Ch. 0+00 to 0+0+400),7 and 8 (0+600 to 0+800) and 16 (Ch.1+500 to1+600) are moderate hazard; the zone 6 (Ch. 0+500 to 0+600),12 (Ch. 1+100 to 1+200),13 (Ch.1+200 to 1+300),15 (Ch. 1+400 to 1+500),19 to 22 (Ch. 1+800 to 2+200) are high hazard zones, and zone no 11 (Ch. 1+000 to 1+100) and 16 (Ch. 1+500 to 1+600) are said to very high hazard zone.

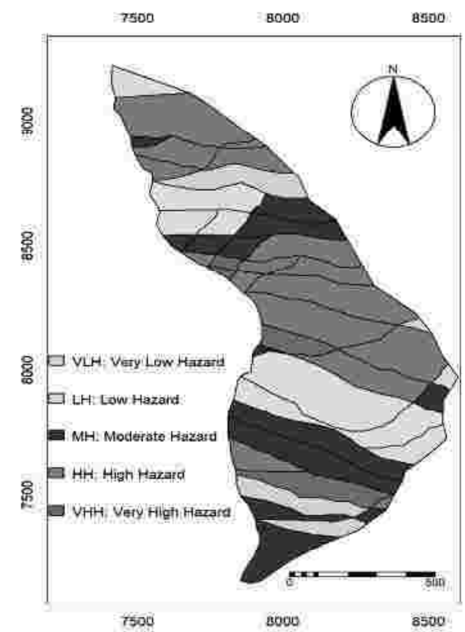


Fig. 1, Hazard map of study area

REFERENCES

Tokuoka, T., Takayasu, K., Yamasaki, H., Tanaka, S., Konomatsu, M., Sah, R. B., and Rai, S. M., 1990, Stratigraphy and geologic structures of the Churia (Siwalik) Group in the Tinau Khola-Binaai Khola area, western central Nepal, Memories of the Faculty of Science, Shimane University, v. 24, pp. 71–88.

A case study of rockfall at Upper Bhotekoshi Hydroelectric Project site to provide suitable mitigation measures

***Darshan Babu Adhikari[1], Manita Timilsina[1], Ranjan Kumar Dahal[2], and Akal Bahadur Singh[3]**

[1]Geotech Solutions International Pvt. Ltd., Kalika Marga, Sanepa-2, Lalitpur, Nepal
[2]Central Department of Geology, Tribhuvan University, Kritipur, Kathmandu, Nepal.
[3]Institute of Engineering, Tribhuvan University, Pulchowk, Lalitpur, Nepal
**Corresponding author: darshanbabu35@gmail.com*

Nepal is a mountainous country characterized by adverse climatic conditions along with high relief, steep slopes, high seismicity, and fractured and weathered rocks making it prone to rockfall hazards. Annually, rockfall events cause tremendous damage to life and property, especially along highways, settlements and hydropower projects in Nepal. Rockfall events are serious engineering challenges to protect infrastructure projects in Nepal's mountainous terrain. On the other hand, 2015 Gorkha Earthquake which was the biggest shaking Nepal has experienced in the last 70 years has jolted these mountains tremendously increasing the risk of rockfall hazard in coming future. Many rockfall events especially along the highways were observed after the Gorkha Earthquake jeopardizing the road safety. Little to no progress has been made till date in mitigating this rockfall hazards in Nepal. This indicated the urgent necessity of suitable mitigating measures of rockfall events for the sustainability of infrastructure in Nepal.

A case study of Bhotekoshi Hydroelectric Project Site is selected for the study of rockfall event caused by Gorkha Earthquake 2015 to provide suitable modern engineering mitigation measures. The study area lies in Jhirpu, Sindhupalchowk District, Nepal approximately 110 kilometers northeast of Kathmandu Valley. During Gorkha Earthquake 2015, the rockfall events had damaged the penstock pipes and the operation of the plant was halted. The area consists of rock types from both geological units: the Higher Himalaya and the Lesser Himalaya divided by the Main Central Thrust (MCT). The area consists of inclined metasedimentary sequences of schist, phyllite, gneiss and quartzite rocks of both units. The objective of this study is to conduct a rockfall simulation to provide suitable mitigation measures.

The research started with data collection, field visits and survey. The rock types are identified and their properties have been determined from literature. The damages caused by rockfall in the penstock alignment of project site are assessed and the size and shape of the fallen rock boulders are recorded. The slope material properties of source zone, transportation zone and impact zone of the rockfall are recorded and a contour map of 1m contour interval is developed of the whole area for rockfall simulation study. The statistical rockfall simulation of the case study area is performed using geostru georock2D software in CRSP (Colorado Rockfall Simulation Programmer) model (Geostru Inc., 2014). 50 numbers of trajectories are used with throw step of 2m. Rockfall simulation is done first without the barrier system to find section with low energy low bouncing height. The profile is again simulated putting the barrier on the section of minimum energy level and bouncing height. If the barrier is able to stop 100% of the rockfall, then the barrier system of the energy class is recommended for the mitigation measures.

The result of rockfall simulation at Upper Hydroelectric project site above penstock alignment shows the kinetic energy, velocity and bouncing height of all the trajectories simulated. Analysing the energy profile and bouncing height profile of all the trajectories, a point in the slope is determined with low energy and low bouncing height. Thus at the point the requited flexible barrier system in accordance to ETAG 027 as per site condition at an angle of 75 degree with respect to slope is chosen to be simulated with the barrier system (EOTA: ETAG 027, 2009). The simulation resulted with 100% of block stoppage at the barrier system, thus mitigating the rockfall problems.

Rockfall simulation depends upon the slope profile; its falling trajectory path. So, any changes in the profile will change its trajectory path and its characteristics. The rockfall protection system barrier (Fig. 1; mitigating measures) is a suitable solution in respect to the current topography but with different scenario the protection system could be different.

Fig. 1, Rockfall Protection Barrier installed at project site (Source: Geotech Solutions International Pvt. Ltd.)

REFERENCES

EOTA: ETAG 027, 2009, ETAG 027: Guideline for European Technical Approval of falling Rock Protection Kits. European Organization for Technical Approval (EOTA).

Geostru Inc., 2014, Georock 2D: User's Manual.

Consequences of rockfall hazard in the Imja Glacial Lake

***Durga Khatiwada, and Ranjan Kumar Dahal**

Central Department of Geology, Tribhuvan University, Kirtipur, Kathmandu, Nepal
**Corresponding author: ddurgakhatiwada@gmail.com*

Imja Glacial Lake is a glacial lake formed at the foot of the Imja Glacier on the lower part of the Imja Glacier. The lake is expanding continuously as there was no lake till 1950 but later couples of ponds were seen. Small supra-glacial pond was found to be increased slowly and now it has attained an area of 1.055 km^2 as the growth rate of the lake increased to 0.025 km^2 from 2000 to 2009. Hence, it is considered as one of the dangerous glacial lake of Nepal. So, in 2016, the lake lowering project by Nepalese Army was done by constructing an outlet and drained over 4 million cubic meters of water from the lake.

This research mainly based on the study of rock fall events from the southern and northern part of the Imja Glacier Lake does not indicate any critical problems of rockfall, but on the northern slope, this study shows that the rock boulders have probability to reach up to the lake after the detachment of rock from the cliff of the Island Peak. Rockfall simulation is performed on southern and north-western slopes (Fig. 1). Four different plots were defined for simulation (Fig. 1). Among them, the plot IV seems to be the most hazardous since the detached boulders on the higher elevation, can enter into the lake with the maximum velocity of 40 m/s and pre- impact energy of 3,577 KJ. This can develop tsunami surge in the lake which can break the moraine embankment of lake. This leads to threat to the communities of downstream. This research confirms that the rockfall hazards in the higher mountain region of Nepal are critical to create flash floods in the river either from glacial lake outburst floods or from snow avalanche. For the case of Imja Glacier valley, the flash flood could be possible in downstream after the tsunami in lake occurs.

Fig. 1, Hazard rockfall zones of the Imja Glacier Lake

Axial monotonic behavior of fully grouted tension anchor in rockfall barrier foundation

***Sunil Poudyal[1], Darshan Babu Adhikari[1], Manita Timilsina[1], and Ranjan Kumar Dahal[2]**

[1]Geotech Solutions International Pvt. Ltd., Sanepa, Lalitpur, Nepal
[2]Central Department of Geology, Tribhuvan University, Kirtipur, Kathmandu, Nepal
**Corresponding author: sunil.poudyal@hotmail.com*

Fully grouted tension anchors in landslide overburden were subjected to pullout tests in a rockfall barrier installation site at a hydropower project in Nepal. A total of five pull out tests were conducted as part of verification of works; three sacrificial tests (Anchors 90 mm borehole diameter and 28 mm GEWI® Threadbar) and two production tests (one anchor 50 mm GEWI® Threadbar and the other 40 mm GEWI® Threadbar in 90 mm diameter borehole). The anchors were embedded 4 m in detritus. Anchor sock was used in one of the sacrificial test anchors to monitor the variation in grout consumption and evaluate the performance of anchor with or without socks. The tests were conducted in accordance to EN 22477-6. Sacrificial tests were carried out with Method B upto the proof load (or until failure) while production tests were carried out in accordance to method A. The results of the tests are presented and characteristics of grout-soil and grout-threadbar are investigated and presented.

Dynamic Quaternary magmatism and volcanic activities in the Japan Alps as revealed by U-Pb zircon dating

Hisatoshi Ito

Nuclear Risk Research Center, Central Research Institute of Electric Power Industry, Abiko, Japan
Email: ito_hisa@criepi.denken.or.jp

The Japan Alps, or Hida Mountain Range (HMR), is known as a place where the highest uplift and erosion occurred in Japan (and probably in the world) through Quaternary time. It is also known as a place where Earth's youngest exposed granite is located (Ito et al., 2013) and also as the source area of some Quaternary widespread tephras that produced gigantic volcanic products. Unraveling magmatic history in this area is crucial to understand the future tectonic evolution and volcanism, which may help to mitigate future geohazards in the central part of Japan.

Here the results of U-Pb zircon dating were applied to date the detrital sediments derived from the HMR (Fig. 1). As a result, it was revealed that the Kurobegawa Granite, Earth's youngest exposed granite, was experienced with two magmatic intrusions of ~2.3 Ma and ~0.9 Ma (Fig. 1a). Moreover, the Takidani Granodiorite, Earth's second youngest exposed granite, experienced only one magmatic activity at ~1.6 Ma (Fig. 1b). The ~1.6 Ma magmatic activity caused caldera collapse (Yari-Hotaka Caldera) and produced gigantic volcanic products that deposited >10 cm-thick tephra (Kd38) as far as 250 km in Boso Peninsula (over Tokyo metropolitan area). Therefore, this research reveals that zircon U-Pb method is a vital tool to reveal Earth's history that was closely linked to human evolution.

REFERENCES

Ito, H., Yamada, R., Tamura, A., Arai, S., Horie, K., and Hokada, T., 2013, Earth's youngest exposed granite and its tectonic implications: the 10–0.8 Ma Kurobegawa Granite. Scientific Report 3, 1306.

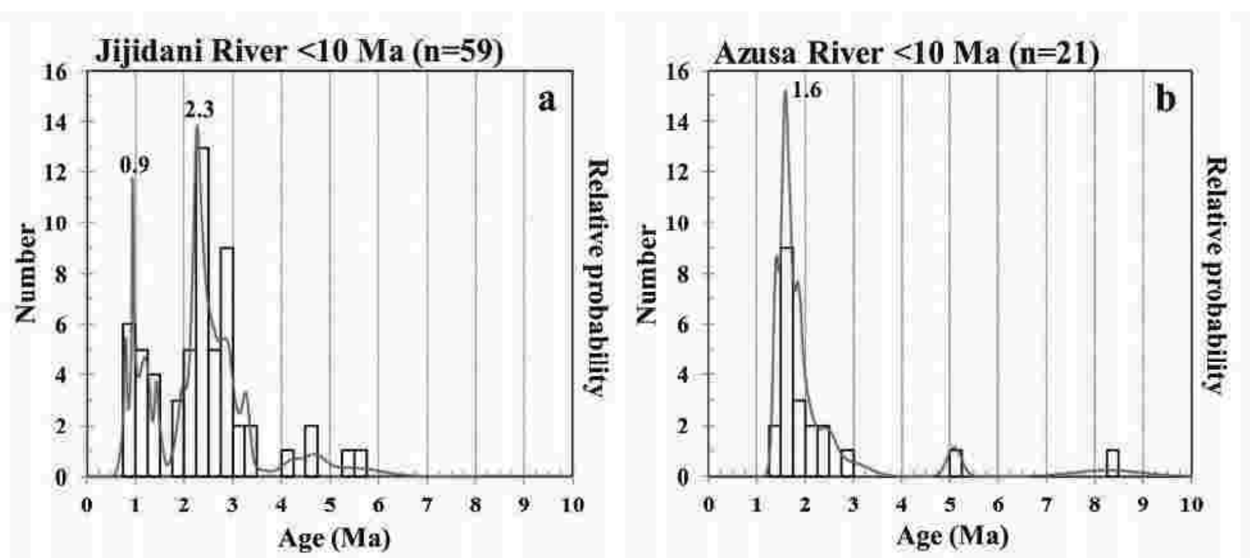


Fig. 1, Zircon U-Pb age distributions of river sands from the Japan Alps

Cross-faults and their role in Himalayan tectonics and natural hazards: a possible example from the Solukhumbu region

Mary Hubbard

Montana State University, Bozeman, Montana 59715, USA
E-mail: mary.hubbard@montana.edu

The magnificent Himalayan mountain belt is the product of the continental collision and continuing convergence between the Indian and Eurasian tectonic plates. Range-parallel fault zones with large displacement are primarily responsible for accommodating this convergence and creating the extreme topographic relief that characterizes these mountains. Recently, there have been several fault zones recognized that are roughly perpendicular to the axis of the mountain range (referred to here as "cross-faults), yet their significance to tectonic processes and natural hazards has generally not been explored. Cross-faults would include the extensional faults that have formed prominent north-south trending graben structures such as the Thakkola Graben in Nepal or the Yadong cross-fault on the western border of Bhutan, which are well-understood as extensional structures. There are, however, other cross-faults that have not been studied in detail, yet their geomorphic expression suggests they are relatively young and their movement history could be closely tied to seismically-triggered landslides. Mukul and Srivastava (2017) and others have noted the presence of the Kosi Fault and the Gish Fault in the region of Sikkim areas. These faults have partitioned deformation of the Main Frontal Thrust, but the deformation crosses into the Greater Himalaya region. I present here a newly-discovered fault, the Bengkar Fault that strikes north-northeast along the Dudh Kosi valley and apparently continues northward into the valley of the lower Khumbu glacier. This structure may also continue southward through Salleri and possibly into the Siwaliks. In the region of Bengkar the fault crosses several landslides and may be partially buried by a younger landslide. The location of these landslides is suggestive that they may have been triggered by movement on the cross-fault. While the major east-west striking faults such as the Main Central Thrust and Main Boundary Thrust have received significant attention by researchers, these cross-faults could also play a significant role in the tectonic development of the range and could also pose a hazard threat to the surrounding region. Cross-faults may represent boundaries of seismic partitioning and therefore are likely to have re-current displacement.

REFERENCES

Mukul, M. and Srivastava, V., 2017, No unique Main Frontal Thrust in the Himalaya?: Geological Society of America Abstracts with Programs. v. 49 (6), doi: 10.1130/abs/2017AM-305740.

Journal of Nepal Geological Society, 2017, Vol. 54 (Sp. Issue)

Assessment of brittleness index of magmatic rocks

Atiye Tu rul, Selman Er, Sinem Eri i , and *Murat Yılmaz

Department of Geological Engineering, Istanbul University, Avcılar, Istanbul, Turkey
**Corresponding author: yimazm@istanbul.edu.tr*

Brittleness, which is defined as a behavior of rock material in rock mechanics, has provided important parameters for understanding excavability, abrasivity, and usability as material, at the present time. Brittleness is generally calculated by the help of strength properties of rocks. The aim of this study is to compare the brittleness properties of magmatic rocks obtained from different parts of Turkey and with their physical and mechanical properties.

Therefore, petrographic, physical and mechanical properties of the magmatic rocks were firstly determined. Then, relations between parameters obtained from experimental studies and brittleness indices were examined with regression analysis. As a result, especially in terms of strength there were determined meaningful relationship between brittleness indices and igneous rocks with B3-B4. When the rocks were divided into granitic rocks and basaltic rocks according to their petrographic properties; the granitic rocks gave higher correlation coefficient values than the basaltic rocks.

Spatial distribution characteristics of major elements in water sources in Kathmandu Valley of Nepal

***Fumitake Nishimura[1], Netra P. Bhandary[2, 3], Ryuichi Yatabe[3], and Junko Nakajima[3]**

[1]*Graduate School of Engineering, Kyoto University, Kyoto, Japan*
[2]*Faculty of Collaborative Regional Innovation, Ehime University, Matsuyama, Japan*
[3]*Center for Disaster Management Informatics Research, Ehime University, Japan*
**Corresponding author: nishimura.fumitake.3n@kyoto-u.ac.jp*

Kathmandu Valley in Nepal accommodates three main cities and a few other town-level settlements. The official population is about 2 million while an unofficial estimation stands above 5 million, which includes temporarily residing people. This is one of the major factors to be considered while developing and managing infrastructures and lifeline facilities such as drinking water supply, drainage facilities, sanitary facilities, and so on. There is a severe scarcity of drinking water in the valley, and whatever is available is also said to be unsafe to drink. Most of the drinking water and water for daily use comes from the valley river system and groundwater pumping. Poorly maintained and old water supply system is supposed to be the major issue to be addressed while planning a better water supply system for drinking as well as daily use purposes.

Kathmandu Valley deposit is composed of various layers of lake sediments, which at the deepest points is believed to be as high as 700 meters. Thick sand layers in the valley ground are one of the major sources of groundwater. Even today, people at different parts of the valley, mainly in the core historical settlements use groundwater for daily use. There are several open sprouts in various parts of the core settlement areas. Moreover, in recent years, as there is a severe shortage of drinking water people use hand pumps to pull groundwater individually, which is often said to have been causing depletion in groundwater level leading to slow subsidence of some parts of the Kathmandu valley ground.

Safe drinking water and enough water for daily use as well other purposes like industrial and agricultural uses are prerequisite to safer and disaster resilient cities. So far, various studies have been made to understand water quality in Kathmandu Valley, but spatial distribution characteristics of the surface and subsurface water have not been adequately studied. In this study, we concentrate in investigating the basic elements present in the Kathmandu Valley water and in spatial distribution analysis to understand the amount of dissolved parameters.

The study was carried out in dry period of year 2007 focusing at a total of 25 locations of surface and subsurface waters. Fig. 1 shows the points of field investigation and water sample collection (i.e, points D1-D6 in Dhobikhola, points G1-G6 in Bagmati river, points B1-B3 in Bishnumati River, points M1-M3 in Manohara River and its tributary, point S1 as subsurface water near point M1, points S2-S4 as subsurface water near Patan Durbar Square, points S5-S7 as subsurface water from Bhaktapur). We used a water quality multi monitoring system W-23XD manufactured by HORIBA Co. Ltd. (Japan). The parameters we measured at the field are: dissolved oxygen (DO), pH, electrical conductivity (ED), oxidation-reduction potential (ORP), water temperature. At the same time, we collected about 100 ml water samples from each location and brought them to Japan for laboratory tests, which consisted of determination of inorganic ion parameters (i.e, cations NH_4^+, Na^+, K^+, Ca^{2+}, Mg^{2+} and anions Cl^-, NO_2^-, NO_3^-, SO_4^{2-}) by ion-chromatograph, total organic carbon by TOC-5000A (manufactured by Shimadzu Corp.) and basic elements (Al, As, B, Ba, Ca, Cd, Co, Cr, Cu, Fe, Hg, Mg, Mn, Mo, Na, Ni P, Pb, Sb, Se, Si, V, Zn). All these parameters were used in cluster analysis as shown in Fig. 2.

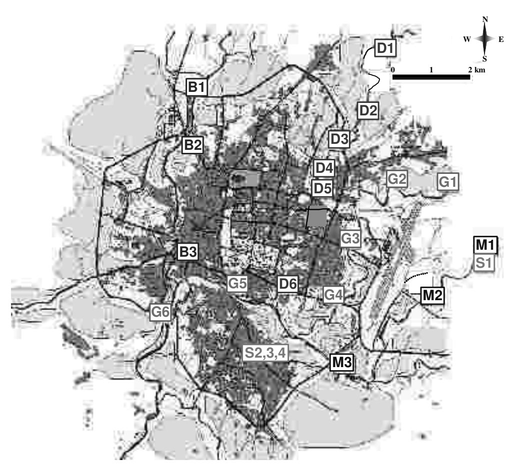


Fig. 1, Investigation and sampling point

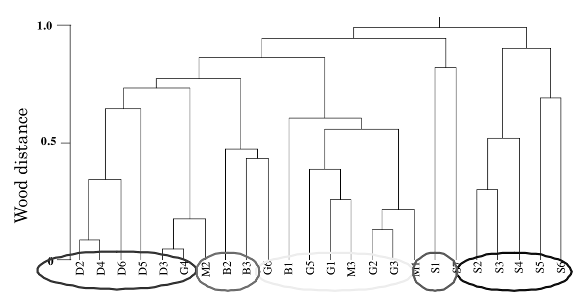


Fig. 2, Cluster analysis result

Geomorphic investigation of the western part of the Chitwan Intermontane Valley, Central Himalayas

Gyanendra Gaire

Seismic activity has been a prominent feature of the youngest orogeny that is the Himalayas. Over the decades the region has been struck with the number of major earthquakes resulting in the formation of various landforms and prominent landscapes or features. Intermontane valleys locally known as duns is one of the features in the Himalayas. The formation of duns is largely controlled by the ongoing tectonism along the Himalayas. Investigation of such duns are essential in knowing the ongoing process of tectonism in the region. This paper marks the region in the southern part of the Siwalik region in central Nepal. They are being close to the epicenter of the devastating 2015, Gorkha Nepal earthquake. This investigation was aimed to identify active faults that have displaced quaternary landforms in the Chitwan valley and also to prepare a detailed geomorphic map of the area in order to stablish link between landforms and structures. The paper includes methodologies such as use of ArcGIS 10.1, SL index analysis and OSL dating has been used to identifying the age of various terraces marked in the region.

Precise location and mapping of the Main Central Thrust Zone in reference to micro-structures and deformation along Khudi-Tal area of Marsyangdi Valley, central Nepal

***Lokendra Pandeya[1], and Kabi Raj Paudyal[2]**

[1]*Department of Mines and Geology, Lainchaur, Kathmandu, Nepal*
[2]*Central Department of Geology, Tribhuvan University, Kathmandu, Nepal*
**Corresponding author: pandeya.lokengeo@gmail.com*

Geological mapping was carried out along the Marsyangdi Valley in the Khudi-Tal area in 1:50,000 scale covering about 142 square kilometers. Main aim of the study was to locate the Main Central Thrust precisely on the basis of lithostratigraphy, micro-structures, deformation and metamorphism. For that an extensive field work was carried out to prepare geological map, micro-structural observation and systematic sampling. A number of thin sections were studied to study the metamorphism, deformation and micro-structures developed in the rocks. Both the Upper Main Central Thrust (UMCT) and the Lower Central Thrust (LMCT) were traced throughout the study area based on the distinct structural, metamorphic and lithological discontinuity. Rock succession of the Khudi–Tal area can be divided into two tectonic zones: the Higher Himalaya and the Lesser Himalaya, respectively. The immediate footwall rocks have been affected by ductile shearing deformation producing a broad thrust zone, i. e., the Main Central Thrust Zone. Based on the dominant lithology, the rocks of the MCT zone that lies in between the LMCT and UMCT, can be grouped into four units from older to younger successions as the Dandagaon Phyllite, the Nourpul Formation, the Dhading Dolomite and the Benighat Slate, respectively. The main rock types found in this zone are pelitic to psammatic schist, calcareous to non- calcareous-quartzite, graphitic schist and dolomitic-marble. Similarly, the rocks of the Higher Himalaya are divided into five units based on the dominant lithology, structure and minerals present. They are kyanite–sillimanite gneiss; banded gneiss and quartzite; banded gneiss I, garnet –kyanite gneiss and banded gneiss II.

The rocks of the region can be divided into two metamorphic zones such as the garnet zone in the Lesser Himalaya and kyanite/sillimanite zone in the Higher Himalaya. Based on mineral paragenesis the rocks of the Lesser Himalaya belong to the epidote- amphibolite facies while the rocks of the Higher Himalaya belong to the amphibolite facies and granulite facies. The rocks of the Higher Himalaya clearly show the metamorphic differentiation as indicated by the zoned kyanite and compositional layering in paragneisses which indicates the high grade of regional metamorphism before the onset of migmatization. The rocks sequences in both the Higher Himalaya and the Lesser Himalaya have undergone polyphase metamorphism and deformation. The Lesser Himalayan rocks experienced first burial metamorphism (M1) followed by garnet grade inverted metamorphism related to the UMCT activity (M2) and followed by retrograde metamorphism (M3) whereas the rocks of the Higher Himalaya have undergone the regional high pressure/ high temperature kyanite/sillimanite- grade prograde regional metamorphism (M1) followed by the (M2) related to ductile sharing which in turn is overprinted by the later post-tectonic retrograde garnet to chlorite grade metamorphism during exhumation. The polyphase deformation is indicated by the cross-cutting foliation and many other features. The deformation phase D1 is associated with the development of the bedding parallel foliation due to burial in both the Higher Himalaya and the Lesser Himalaya. Isoclinal folds and crenulation cleavage were developed before the collision categorized as D2. Development of nearly N-S trending mineral and stretching lineation, south vergent drag folds, folded S2 cleavage and microscopic shear sense indicators, rotated syn-tectonic garnet grains, etc, were developed during the deformation D3 related to the ductile shearing along the MCT. Various brittle faults and shear zones cross- cutting all earlier features were developed during D4 during upheaval. The rocks in the MCT zone are affected by intense sharing and mylonitization as indicated by the presence of many mylonitic structures in the thin sections throughout the Lesser Himalaya in the area. Features like polygonization and ribbon quartz with evidence of sub-grain rotation, mica fish, syn- tectonic rotated garnet grains indicate the ductile shearing in the MCT area suggesting the dynamic recrystallization in the MCT zone whereas the rocks of the Higher Himalaya show the evidence of recrystallization under static condition. The MCT zone was mapped precisely based on the microstructures and deformation as mentioned above. A number of landslides of different types and dimensions are distributed along the MCT zone.

A bibliometric survey of scientific publications (1980-2017) on natural geological hazards in Nepal

***Pitambar Gautam[1], and Ranjan Kumar Dahal[2]**

[1]*Creative Research Institution, Hokkaido University, Sapporo, Hokkaido, Japan*
[2]*Central Department of Geology, Tribhuvan University, Kirtipur, Kathmandu, Nepal*
**Corresponding author: pgautam2000@yahoo.com*

In view of the sparse bibliometric studies on Nepal (Gautam, 2017), we present the tentative results of a bibliometric survey of 495 scientific publications dealing with natural geological phenomena (such as landslide, earthquake, karst, glacier-related flood) and their engineering geological aspects related directly or indirectly (in the context of a broader Himalaya-wide perspective) with Nepal. The Web of Science (WOS) Core Collections database modules (SCIE, SSCI, A&HCI) were used to retrieve the documents (articles, reviews, letters and notes) using a complex search strategy targeted at publications related to all possible keywords for the phenomena mentioned above, the "Engineering, Geological" WoS subject category, and relevance to Nepal as shown by the country name at least in one of the followings: title, keywords, abstract, and author addresses. Documents related purely engineering works, landslide victories and mass movements related to politics etc. were removed by using appropriate search filters and after manual screening of the search results. A brief summary of data processed using *bibliometrix* (Aria and Cuccurullo, 2017) and visualization by VosViewer (Van Eck and Waltman, 2014) is given in Table 1 and Fig. 1 below.

REFERENCES

Aria, M., and Cuccurullo, C., 2017, *Bibliometrix*: An R-tool for comprehensive science mapping analysis, Journal of Informetrics, v. 11(4), pp 959-975. DOI: 10.1016/j.joi.2017.08.007.

Gautam, P., 2017, An overview of the Web of Science record of scientific publications (2004–2013) from Nepal: focus on disciplinary diversity and international collaboration, Scientometrics. DOI: 10.1007/s11192-017-2538-0.

Van Eck, N. J., and Waltman, L., 2014, Visualizing bibliometric networks. In Y. Ding et al. (Eds.), Measuring Scholarly Impact, pp. 285–320, DOI:10.1007/978-3-319-10377-8_13.

Table 1: A brief summary of bibliometric indicators

Authors (Ndocs)	Sources (Ndocs)	Author Keywords (Ndocs)
AVOUAC,JP(24)	NATURAL HAZARDS(31)	NEPAL(89)
BOLLINGER,L(24)	GEOPHYSICAL RESEARCH LETTERS(27)	HIMALAYA(69)
SAPKOTA,SN(16)	JOURNAL OF ASIAN EARTH SCIENCES(27)	LANDSLIDE(30)
DHITAL,MR(15)	J GEOPHYSICAL RES-SOLID EARTH(19)	EARTHQUAKE(26)
BHANDARY,NP(14)	GEOPHYSICAL JOURNAL INTERNATIONAL(18)	LANDSLIDES(24)
DAHAL,RK(14)	MOUNTAIN RESEARCH AND DEVELOPMENT(16)	NEPAL EARTHQUAKE(20)
YATABE,R(13)	CHINESE J OF GEOPHYSICS-CHINESE ED(15)	HIMALAYAS(18)
BILHAM,R(12)	GEOMORPHOLOGY(15)	GORKHA EARTHQUAKE(16)
MUGNIER,JL(12)	EARTH PLANETS AND SPACE(14)	CLIMATE CHANGE(12)
REGMI,AD(12)	CURRENT SCIENCE(12)	GIS(11)
CATTIN,R(11)	TECTONOPHYSICS(12)	GPS(11)
KUMAR,A(11)	GEOMATICS NATURAL HAZARDS & RISK(9)	HAZARD(11)
RAJAURE,S(10)	EARTH AND PLANETARY SCIENCE LETTERS(9)	KATHMANDU VALLEY(11)
VARUM,H(9)	GEOLOGY(8)	NEPAL HIMALAYA(10)
VERGNE,J(9)	LANDSLIDES(8)	TECTONICS(9)
FORT,M(8)	NATURAL HAZARDS AND EARTH SYSTEM SCI(8)	EARTHQUAKES(8)
JOUANNE,F(8)	ENVIRONMENTAL EARTH SCIENCES(7)	SEISMIC HAZARD(8)
KAYASTHA,P(8)	J OF THE GEOLOGICAL SOCIETY OF INDIA(7)	SEISMICITY(8)
MCKINNEY,DC(8)	SEISMOLOGICAL RESEARCH LETTERS(7)	VULNERABILITY(8)
PANDEY,MR(8)	ARABIAN JOURNAL OF GEOSCIENCES(6)	ASIA(7)

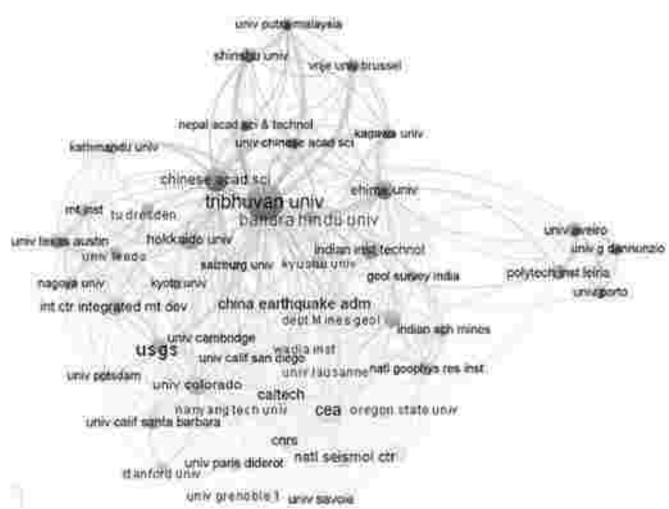


Fig. 1, Bibliographic coupling of worldwide organizations engaged in research on natural geological hazards in Nepal (No. of minimum documents = 5)

Geophysical study on moraine dam of Imja Glacier Lake in Eastern Nepal using electrical resistivity tomography method

***Pushpa Raj Dahal[1], Kabi Raj Paudyal[2], and Sudhir Rajaure[3]**

[1]*Ministry of Irrigation, Sighadarbar, Kathmandu, Nepal*
[2]*Central Department of Geology, Tribhuvan University, Kirtipur, Kathmandu, Nepal*
[3]*Department of Mines and Geology, Lainchaur, Kathmandu, Nepal*
**Corresponding author: pushpardahal@gmail.com*

Glacier Lake Outburst Flood (GLOF) is one of the potential disaster of Nepal. A very few work is carried out to study the geophysical condition of such moraine dams in Nepal in the past. The Imja glacial lake is considered as one of the fastest growing glacial lake with high risk of GLOF. The internal structure of moraine dams, especially the distribution of buried ice blocks and permafrost materials is one of the key factors in assessing GLOF risk. Subsurface conditions of the moraine material such as location of buried ices, seepage areas and material distribution were considered to be surveyed in detail.

The geophysical study of dam was carried out by using Dipole –Dipole array of electrical resistivity method. The study presents the results regarding the use of electrical resistivity surveys in the assessment of the subsurface buried glacier ice and permafrost zones within the dam of the Imja Glacier Lake. The interpretation of resistivity data at end moraine of Imja Glacier Lake is based not only on specific resistivity values, but also with field observations and correlation with previous studies. The maximum depth of information obtained from the modeling is about 25 m and; highest and lowest values of resistivity ranges from 117 Ωm to 2682240 Ωm. The distribution of major subsurface materials from lowest resistivity value to highest resistivity values are classified as saturated moraine, dead ice and frozen moraine. The distribution of dead buried ice in moraine dam is found to be heterogeneous (Fig. 1). The minimum and maximum depth of dead ice from surface is about 0 m to 20 m at various locations. Based on the information of this study, an open channel was cut through the lake to lower its level and the result is found to be successful.

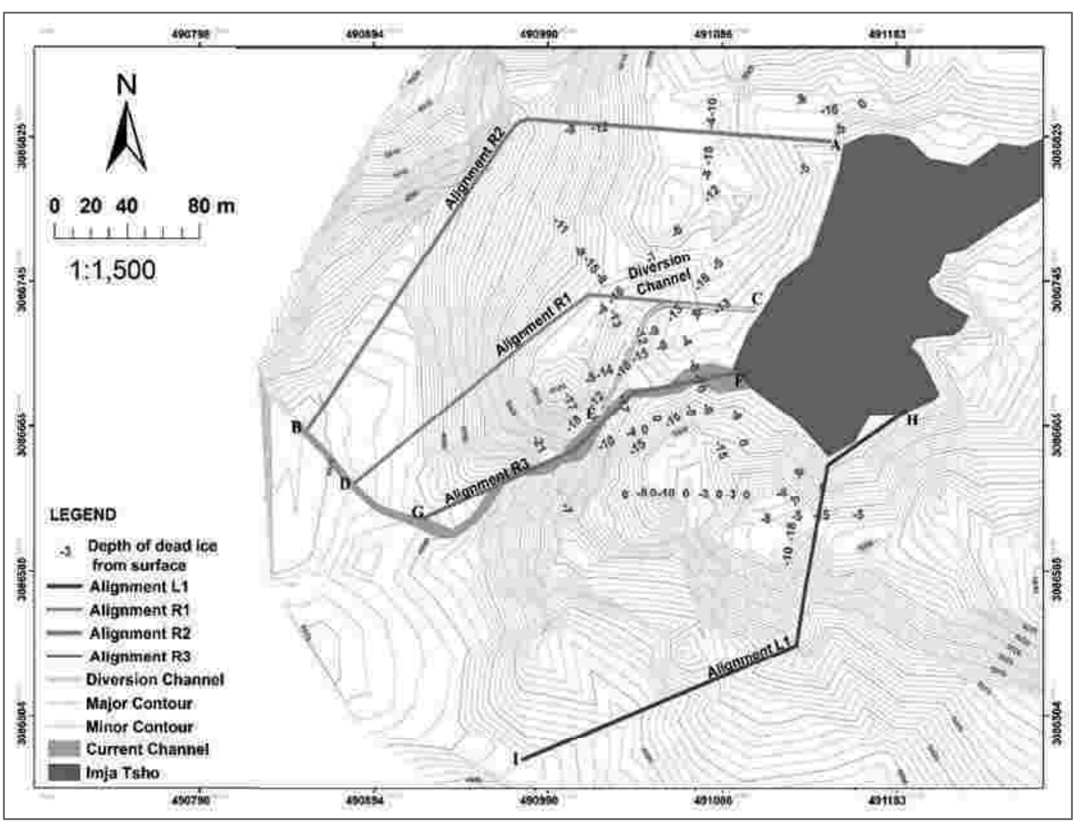


Fig. 1, Dead Ice distribution map of Imja Glacier Lake outlet channel at end moraine

The study on the mechanism of hydraulic fracturing in cohesive zone of embankment dam cores (literature review)

***Samjhana Poudel, Samson Ngambi, and Adegoke Olubanwo**

Department of Civil Engineering Architecture and Building, Faculty of Engineering and Computing Coventry University, UK
**Corresponding author: samjhanapoudel21@yahoo.co.uk*

Embankment dam failure is a major challenge for dam engineers these days. Failures of dams can result in greater loss of human life and property than failure of the most other man-made structures. Previous researches have investigated that the failure and unsatisfactory performance of dam in UK are associated with internal erosion by 55%. So they concluded that the most serious hazard to earth dams as they age in service is associated with internal erosion.

Internal erosion is associated with hydraulic fracturing mechanism which is initiation and propagation of cracks in cohesive zoned of earth filled dams. Hydraulic fracturing leads to massive concentrated leakage breaching the dam core resulting in partial and complete failure of dam. It is considered that hydraulic fracturing in embankment dam was the major cause of failure in some of the famous dam including Teton Dam (USA), Balderhead Dam (UK) and Hytterjuvet Dam (Norway). This research paper sets out to review hydraulic fracturing mechanism investigated by past researchers and also reviews on different case histories of unsatisfactory performance of dam due to hydraulic fracturing.

The mechanism of hydraulic fracturing is still an unsolved problem. It is believed that hydraulic fracturing in dam induces and propagates cracks in the dam and these cracks lead results in concentrated leakage in earth fill dam. This phenomenon is rapid during reservoir filling resulting in unsatisfactory performances of dam.

In the paper authors summarize the different concepts and analysing methods for understanding the mechanism of hydraulic fracturing and calculation of critical water pressure which are vital to induce hydraulic fracturing and come with idea that different researchers have their own presumptions and perception based on experimental, theoretical and field tests analysis on the mechanism of hydraulic fracturing.

The key findings on this report are based on three case histories on failure of embankment dam (Teton Dam, Balderhead Dam and Hytterjuvet Dam). Case histories of hydraulic fracturing in embankment dams and boreholes are reviewed. It is found that hydraulic fracturing in dams is often associated with rapid reservoir filling and zones of low stresses. Previously proposed criteria for hydraulic fracturing are outlined. It is found that no existing theory adequately explains fracturing observed in laboratory tests. Characteristics of dispersive clays and the methods of identifying them are reviewed. It is found that no single test provides results that have a satisfactory level of reliability

Study on the deformation structure developed in a gravel layer by fault movement based on model experiments

Shiro Tanaka

Central Research Institute of Electric Power Industry, Chiba, Japan
E-mail: tanakasr@criepi.denken.or.jp

The displacement of the basement rock by fault movement causes deformation of the overlying sediments and leads to the development of a shearing structure. In the case of fine-grained sediments such as sand or mud layer, a clear shearing structure frequently develops in the overlying sediments. Although rearrangement by rotation of clasts is observed when the overlying sediment is a gravel layer, some shear planes were not clearly visible. Therefore, when a gravel layer covers the level difference of the basement rock with a fractured zone, following confusion may arise: either the structure observed in the overlying sediment is a deformation structure accompanying fault movement or it is a buried differential erosion geographical feature. As an effective method of examining the mode of development of the deformation and shearing structures of the cover layer via fault movement, a fault model experiment using a well-sorted sand sample was performed (Ueta and Tani, 1999). In the present study, a fault model experiment was performed using a mixed sample of grit for clarifying the features of the deformation and shearing structures developed in a gravel layer.

A soil tank prepared from acrylics was used for the experiment. The fault movement was simulated by displacing the bottom of the soil tank. No. 8 silica sand was used as the material to simulate the matrix of a gravel layer, and No. 3 and No. 1 gravels were used as clasts. The mixture ratios of No. 8, No. 3, and No. 1 gravels were 75 wt%, 10 wt%, and 15 wt%, respectively, and the medians of the particle diameter were approximately 0.08 mm, 2 mm, and 6 mm, respectively. The layer thickness of the simulating ground was approximately 50 mm. To preliminarily examine the difference in the development form of shear planes in different water conditions, the water conditions of the simulation ground were as follows: dryness condition, wet condition (moisture content approximately 26%), and inundation condition. The dip angles of the fault in the basement rock were 60°, 75°, and 90°, and the reverse fault movement was simulated by raising the hanging wall. The slip rate of the vertical component was set as 0.01 mm/s. In the experiment, displacement was sustained until the vertical component reached 20 mm or more. X-ray computed tomography scan of the soil tank was conducted every 2-mm vertical displacement, and the 3D form of the shear plane in the simulation ground and the movement of clasts were observed.

As the basic case, the deformation structure and shear plane developed in the sand layer with the reverse fault movement of a soil tank are described below. When a level difference occurs in the basement rock, shear plane 1 is generated from on the level difference. This plane develops with an angle lower than the inclination of the fault, and the inclination of the plane becomes low near the surface. An increase in the displacement leads to the generation of shear plane 2, which acts as the main fault. This plane has almost identical dip as the fault of a basement rock, and in the upper part, the shear plane 2 has low inclination and reaches the ground surface. In this stage, shear plane 1 also reaches the surface. When the amount of displacement increases further, the normal fault group, which is inclined in the direction opposite to that of the reverse fault of the basement rock, develops into a hanging wall side and forms a graben. At this time, the surface of the hanging wall side is unstable, and may collapse toward the footwall side with an increase in the amount of displacement.

The results of the fault model experiment for the gravel layer indicate that the shearing structure confirmed that the process of shearing in the gravel layer was similar to that in the sand layer. In other words, a shear plane is formed in the order of shear planes 1 and 2 with an increase in the amount of fault displacement. In the gravel layer, the rotation of clasts was mainly observed in a fan-shaped region between shear planes 1 and 2. The rotation of clasts is particularly remarkable on the shear plane. Moreover, the clast also causes the rotation of the hanging wall side of shear plane 2 as it is dragged at the footwall side. The shear plane that developed in the gravel layer exhibits the tendency for delaying the progress to the upper part as compared with the development of the shear plane in a sand layer. Moreover, at the location of the clast in the extended part of a shear plane, the shear plane bypasses the clast or diverges from the clast, and hence, the shear plane is not clearly observed. Therefore, although the shear plane is not clearly developed at locations with high clast density, it clearly develops in the overlying sand layer. The distributions of shear planes that developed in the simulation ground under wet and inundation conditions were similar to those developed in the dryness condition although the shear planes were partially indistinct in X-ray CT images.

REFERENCES

Ueta, K., and Tani, K., 1999, Deformation of Quaternary Deposits and Ground Surface Caused by Bedrock Fault Movements (Part 2) - Normal and Reverse Fault Model Tests- CRIEPI Research Report, U98048, 40p.

Early-warning for pilling-induced sinkhole in Xiamao village of Guangzhou city, China

***Yan Meng, Long Jia, and Mingtang Lei**

Institute of Karst Geology, CAGS， Guilin 541004， China
Key Laboratory of Karst Collapse Prevention, CAGS， Guilin 541004， China
No.50, Qixing Road Guilin City, Guangxi Province, China
**Corresponding author: sinkhole@163.com*

Unclear genetic mechanism causes unable early warning to the punching-induced collapse sinkhole during the pile foundation construction. To build geologic model that can ascertain the cause and obtain the prediction criterion value by the mechanical and statistical analysis. We studied 8 typical collapse cases from the nature and structure of soil layers, the characteristics of cave roof, and the hydrodynamic conditions of groundwater. Three typical geologic models had been built including Sand Leakage, Water Hammering, and Roof Collapse, respectively in Xiamao village of Guangzhou, China. The results confirm that the thickness of sand (Hs), the water head height of water hammer pressure (Hw), and the thickness of the cave roof (Hi) can be used as the early-warning indicators for the different type of the pilling-induced collapse sinkhole.

Rock mass property evaluation based on borehole wall images by an ultrasonic scanner (USS) at Horonobe Underground Research Laboratory, Japan

***Y. Otsuka[1], T. Ishikawa[1], K. Tajima[1], T. Wada[2], Ö. Aydan[3], N. Tokashiki[3], T. Sato[4], and K. Aoyagi[4]**

[1]*Earth Scanning Association, Yokohama, Japan*
[2]*RaaX Co., Ltd., Sapporo, Japan*
[3]*University of the Ryukyus, Okinawa, Japan*
[4]*Japan Atomic Energy Agency, Horonobe, Japan*
**Corresponding author: ootsuka-yasunori@cb3.so-net.ne.jp*

Discontinuities, such as faults and fractures exist even in Neogene soft sedimentary rocks. These discontinuities play an important role for determination of physical, mechanical and hydraulic properties of rock mass. In the geological disposal of high-level radioactive wastes, these data should be obtained for design of engineered barrier system and safety assessment. Rock mass properties are useful information for quantitative rock mass classification, and are also important information for design and construction of underground facility and judgment of waste installation.

Ultrasonic wave reflection intensity of the borehole wall drilled from the bottom of the East Access Shaft in the Horonobe Underground Research Laboratory, Hokkaido, Japan, was obtained using an ultrasonic scanner (USS). In this study, we compared results of USS observation with core logging data including core observation, optical digital scanner (ODS) observation, and result of Needle Penetration Index (NPI) tests. The results indicate that ultrasonic wave reflection intensity has a good correlation with other observation results. USS observation and NPI tests are useful techniques for determination of detailed rock mass characteristics.

A preliminary study on classification of urban road collapses and prevention measures

***Yuanbin Wu[1,2], Weiquan Luo[1,2], Zongyuan Pan[1,2], and Renchao Yin[1,2]**

[1]*Institute of Karst Geology, CAGS, Guilin, Guangxi 541004, China*
[2]*Laboratory of Karst Collapse Prevention, CAGS, Guilin, Guangxi 541004, China*
**Corresponding author: wuyb@karst.ac.cn*

In recent years, urban road collapse has become one of main types of urban geologic hazards and has been attracting an increase of public attention. Urban road collapses are not only distributed in karst area but also in non-karst area as well, such as Lanzhou, Chengdu, Beijing, Shanghai, Harbin and so on. Generally, the collapse is usually small in scale and single pit. These collapses are usually concerned to be public emergency issues and cause some damages or injuries. Research on classification of urban road collapse was few in number. Based on potential collapse recognizing in prophase, emergency response plan in metaphase and engineering treatment in anaphase, urban road collapse can be classified into four categories: karst type, pipe type, bomb shelter type and construction quality type, respectively. Furthermore, this study suggests that the root cause of urban road collapse is the formation of the cavity because of erosion or loess collapsibility due to groundwater, rainwater or leakage water from pipe. Meanwhile, the traffic loads accelerate the progress.

.

Dry storm period sediment dynamics of southern tributaries of the Bagmati River, Kathmandu Valley, Nepal

***Dinesh Raj Sharma, and Naresh Kazi Tamrakar**

Central Department of Geology, Tribhuvan University, Kirtipur, Kathmandu, Nepal
**Corresponding author: dineshrajsharma@hotmail.com*

The Godavari Khola, Kodku Khola, and the Nakhu Khola are northward flowing storm-fed perennial streams, which are originated from the southern mountains of the Kathmandu Valley, thereby contributing the mainstream Bagmati River in the central portion of the valley. To obtain sediment dynamics of these streams, their morpho-hydrology and sediment transport were determined and stream flow velocity was measured at ten different transects along each stream using a current meter. Sediment transport capacity and competency, as well as sediment yields of each of the basins of the streams were evaluated. Based on median grain size, all the streams fall into the gravel bed streams. Discharge (Q) of the Godavari Khola, Kodku Khola and the Nakhu Khola were in the ranges of 0.007 to 0.065 m^3/s, 0.020 to 0.142 m^3/s and 0.015 to 0.134 m^3/s, respectively. No gradual increase in discharge with respect to the distance from the origin of the stream was obtained, meaning that the discharge fluctuated along the stream course. This anomaly was due to human influences; change in landuse pattern and structures and from the effect of local tributaries. The Kodku Khola and the Nakhu Khola show relatively low competence for the incipience of the median grain sized sediment (ratio of dimensionless boundary shear stress to dimensionless critical shear stress), where 70% of the transects in the Kodku Khola and 60% in the Nakhu Khola are incompetent, compared to the competence of the Godavari Khola, where only 40% of the transects are incompetent. Bed load transport of the Godavari Khola, Kodku Khola and the Nakhu Khola ranged respectively from 0.1 to 57544 tonnes/day, 0.1 to 130697 tonnes/day, and 0.01 to 10141 tonnes/day. Suspended sediment load of the Godavari Khola, Kodku Khola and the Nakhu Khola were 3–216 tonnes/day, 2–147 tonnes/day, and 13–249 tonnes/day, respectively. It was observed that the bed load dominated over the suspended load in each of the streams. Despite of wide variation of bed load and suspended load in individual streams, the higher loads were attributed to stream gradient, landuse pattern and mining activities. Relatively high bed load transport can be attributed to availability of gravelly terrace deposits as sediment sources in the stream basins. Sediment yields generally ranged between magnitude of 1 and 10 tonnes/km^2/year, but at places sediment yields varied from 100 to 1000 tonnes/km^2/year in the Godavari and the Kodku Kholas, and 10 to 100 tonnes/km^2/year in the Nakhu Khola. These wide fluctuations in sediment yields at different transects particularly in the Godavari and the Kodku Kholas suggest sediment input from the local contributors (streambank erosion, anthropogenic thrusts, etc). The sediment yields tended to increase as the increase in dimensionless shear stress ratio, and also as the increase in sediment load. Sediment yields nearby the exits of the Godavari Khola, Kodku Khola and the Nakhu Khola during the dry storm period were 8.72, 0.44 and 7.12 tonnes/sq.km/day, respectively. These figures suggest that the sediments leaving the stream basins are relatively low despite of notable sediment yields along the transit of the streams.

Lumle landslide of Kaski District: causes, characteristics and lesson learned

***Narayan Adhikari, and Gautam Khanal**

Department of Mines and Geology, Lainchaur, Kathmandu, Nepal
**Corresponding email address: gs.narayan@hotmail.com*

The Lumle Village lies in the Kaski District of West Central Nepal. Geologically this area belongs to the Kuncha Formation of the Lesser Himalaya. The settlement lies in gentle slope and rests over the old colluvium composed of fragments of phyllites and metasandstone. There is a very steep rock slope north to the village. On mid-night of 29th July 2015, part of this village was swept away by a catastrophic landslide killing 28 people and leaving 42 people injured. Although a sudden burst of a 30 m^3 capacity water storage tank was considered to be the main reason for the landslide to occur, this study disavows this sole cause for the catastrophe. Results of the study show that this complex slide was occurred primarily due to the intense rainfall which was further worsen by the anthropogenic factor. This interpretation is supported by the records of the rainfall from the Department of Hydrology and meteorology which shows that the Lumle area had suffered a 24 hour rainfall of 289 mm at that day, which is the significantly higher than the maximum 24 hour rainfall of past 5 years. Field evidences, interview with local people and orientation of discontinuities of the bedrock lying in the steep rock slope above the gentle slope of the Lumle Village show that a major rock fall/ slide was started from the steep rock slope after the heavy rainfall. Later, the debris from the rock fall/slide along with the loose colluvial soil started to flow down which was temporarily blocked by a poorly constructed water storage tank full of water on its way down to the Lumle village. This caused accumulation of more debris at back side of the water storage tank. Finally this water storage tank was pressured beyond its capacity causing its sudden outburst and the debris from the landslide along with the water forcefully hit the settlement causing loss of 28 lives and 13 houses.

The Lumle Landslide is an important lesson for disaster risk reduction practitioners of Nepal. Local people from the Lumle area report's the study team that the people of the village used to divert the water from the surface runoff from the monsoon rainfall toward the stream in the past years before the slide. However, it was neglected in the later days and the runoff from the monsoon water was forming small gully toward the village and it was left unaddressed until the disaster happened. Similarly, a large water storage tank was poorly constructed just above the settlement in improper location. Proper management of the surface runoff and proper construction of the structures like the community water storage tank can largely contribute to reduce the risk of disaster in many such areas of Nepal. Also, if an early warning system is established, so that people are timely warned about the intense rainfall in such area, probably the loss from such disaster could be significantly reduced.

Uplifted terraces and natural exposures as a marker to quantify the past earthquakes: evidence from Butwal Area, western Nepal

***Prakash Pokhrel, Bishwo Raj Silwal, and S. N. Sapkota**

Department of Mines and Geology, Lainchaur, Kathmandu, Nepal
**Corresponding author: pku.pok@gmail.com*

In the Himalayan region, earthquakes are confined to the active plate boundary forming the Himalayan seismic belts. Nepal lies in the central part of such a seismic belt. Since historic and pre-historic time, the Himalaya has experienced several major earthquakes. Very few earthquakes data are instrumentally recorded. Therefore, location of many known historic earthquake are also ambiguous. Every mega and great earthquake leaves its imprint in morphology. Quantifying such morphology is crucial to date the past earthquakes. In this connection, present study was carried out around Butwal in western Nepal. Altogether 21 pits were dug on uplifted terraces and 44 charcoal samples were collected for the radio carbon (c14) dating. Evidence of recent faulting was also mapped in different places where recent fluvial deposits were overridden by old Siwalik beds. These exposures warrant the detailed refreshing and logging. Such natural exposures are the proof of active faulting but difficult to quantify its timing. Considering this constraint, we have marked two successive scarps around this area, which will be further studied by paleo-seismological trenching in future. Steep river gradient, rapid rate of erosion, deposition and urbanization makes some difficulties to map the Main Frontal Thrust in the study area. This talk will focus on methodology, preliminary results from c14 dating and natural exposure of the MFT in the area.

Geomorphic criteria for active fault mapping: a case study from Badi Gad Fault in West-Central Nepal of the Lesser Himalaya

***Kumar Timalsina, and Kabi Raj Paudyal**

Central Department of Geology, Tribhuvan University, Kirtipur, Kathmandu, Nepal
**Corresponding Author: ktimalsina62@gmail.com*

The Lesser Himalaya is a fold-and-thrust belt of the Himalaya. In Nepal Himalaya, several active faults are identified and mapped by many researchers in the past. The Badi Gad Fault is one of them. In the present study, an attempt is made to map this fault based on geomorphic criteria. For this purpose a detailed geological map was prepared from Ridi to Shantipur area in 1:25,000 scales covering the eastern part of the Badi Gad Fault. During the field work, several geological as well as geomorphic evidences of the existence of fault are found. Some of the important evidences are also found under the aerial photo observation. These evidences include the presence of shear zones, clustering of large and several landslides along the certain zone, river course diversion, terrace tilting, fault scarps etc. The Badi Gad Fault is traced out continuously, about 30 Km extension length, from Ridi to Shantipur area. Under aerial photo, the fault even can be extended far NW direction. The fault follows the moderate hills of the left bank of the present course of the Badi Gad River. Major shear zone are found in the Tal Khola, Aslewa, Eksingaun, Juhan, Gultung, and the Rupakot areas and studied in detail. Geological evidences of these shear zones are represented by the wide zone of fault gauge, fault breccias, silickensides, spring lines and mass movements. In addition to shear zones, tilted river terraces in Pul Camp, and Wamitaksar area, river course diversion of the Lumdi Khola and fault scarp at Bhanjyangaun of Aslewa are other geomorphic evidences of the fault. Existence of the fault is also evidenced by the clustering of several landslides that are found in the presently prepared landslide susceptibility maps.

Geotechnical investigations for supercritical Buxar Thermal Power Project 1320 MW (2x660 MW) at Chausa, Buxar, Bihar, India

Parveen Gupta, R. K. Ahirwar, and *Naveen Kumar Kanyan

Buxar Thermal Power Project, STPL (Subsidiary of SJVN Ltd, PSU under Government of India)
**Corresponding author: naveenkanyan@gmail.com*

SJVN Limited is a joint venture between the Government of India and Government of Himachal Pradesh. It intends to set up Buxar Thermal Power Project (Buxar TPP) of 2x660 MW near Chausa village in Buxar District of Bihar. The latitude and longitude of the project site are 83° 52' 49"N and 25° 27' 51"E, respectively and falls in Survey of India Toposheet 63 O/15.

The geology of the Buxar (Chausa) project site located at the southern side of the Ganga River in Bihar is represented by alluvium deposits of the river Ganga. In general, the litho-units at subsurface level consist of admixture of silty-clay with fine sand, clayey-silt with sand, clayey-silt, gravel, etc.

Subsurface faults and lineaments occur to the north of the site whereas Son-Narmada and other faults and shear zones occur to the south. The project site at Chausa lies in seismic zone-III as per the seismic zoning map of India as incorporated in Indian Standard Criteria for Earthquake Resistant Design of Structures IS:1893-(Part I) 2002: General Provisions and Buildings. Historical and instrumentally recorded earthquake data provided by India Meteorological Department, New Delhi show that the region has experienced earthquakes up to magnitude 8.3. The prominent amongst them are the Bihar–Nepal Border earthquake of January 15, 1934 (M=8.3); Bihar–Nepal Border earthquake of August 21, 1988 (M=6.4); the Jabalpur earthquake of May 22, 1997 (M=6.0); and the Nepal earthquake of April 25, 2015 (M=7.8).

Geotechnical investigation was carried out by different geotechnical methods like drilled boreholes, Standard Penetration Test (SPT), collection of samples for lab Test, water table recording at site, permeability test, Electrical Resistivity Test (ERT) and Seismic Refraction Test (SRT), etc. On the bases of geotechnical study different types of foundation are found to be suitable for different types of structure in this project. Pile foundations are suggested for Stream turbine Building, Stream Generator Building, Satalytic reduction, ESP and Chimney. Footing foundations are suggested for Switch Yard, Air compressor, O & M workshop, WTP, and Township. Raft foundation recommended for Wagon Trippler and IDCT.

Study on hidden danger recognition methods in geological hazards of karst collapse

Jia Long

Institute of Karst Geology, CAGS, Guilin 541004, China
Key Laboratory of Karst Collapse Prevention, CAGS, Guilin 541004, China
No.50, Qixing Road Guil City, Guangxi Province, China
E-mail: jialong@karst.ac.cn

Geologic hazard of karst collapses occur frequently in the south of China in recent years. The study of karst collapse mostly lies in genetic mechanism, but there are few researches about the symptom and identification of the hidden danger before the collapse of the ground. The abnormal early hidden danger signs (ground sign, underground sign and hydrodynamic sign) of karst collapse are studied, further the corresponding identification techniques and methods have been carried out such as surface survey techniques (satellite remote sensing, the drone, etc.), underground detection technology (ground penetrating radar, micro gravity, micro motion, etc.), and monitoring technique of groundwater dynamic condition. And the conditions, operation methods and implementation plan of these techniques are explored. Finally, all kinds of techniques and methods can be compiled each other to form a comprehensive system for identifying hidden danger of karst collapse. This paper aims in identifying the early hidden dangers of karst collapse geological disasters. It has important theoretical, technical and social significances in order to minimize the impact of disasters on the people's life and the environment.

Role of inherent rock mass properties and their geological settings in influencing the phenomena of rock bursting

Prashant Rai

Engineering Geology & Geotechnical Division, NHPC Limited
E-mail: prashantrainhpc@gmail.com

The large numbers of underground structures like power house, desilting chambers and head race tunnels have been executed in varying geological terrains and different ground behaviors. One such behavior pattern is rock bursting. It is understood that, such kinds of failure are related to increased shear trends in rock with relatively high compressive strength and Young modulus ratios. However, it is also often observed that in the similar shear stress level and strength level, the rock bursting phenomena do not occur as expected and/or anticipated. This brings to light the possible influence of certain inherent rock mass properties and their geological settings in the occurrences of rock bursting. This paper aims to explore the roles of such inherent rock mass properties influencing the rock bursting phenomena.

In situ stresses patterns are controlled by the tectonic influence of the area and their assessments through established scheme of mathematical models have serious limitations. Moreover, empirical rock mass characterization system such as RMR, Q, etc. towards assessing the rock mass have been found to be inaccurate particularly in case of widely varying factors influencing rock bursting failure. In such circumstances, where there exist significant unpredictability in actual stress and strength level, a need is to identify other parameters influencing the occurrence of rock bursting phenomena.

In this regard, influence of rock texture, porosity, permeability, Young modulus, brittleness, mi, c and Ø values, etc. have been investigated. Further, external influences such as groundwater, rate of loading, method of advancement, excavation cycles, etc. are known to contribute to the phenomena of rock bursting.

The detailed analysis of the topographical conditions has also been done to study the variations in in situ stress conditions negotiated by the tunnel. Finally, geological setting particularly referring to geological structure of the area has been successfully established to evaluate their influence on scale comparable to the excavation cycle.

Geological and geotechnical aspects and extended spillway arrangement of Subansiri Lower HE Project, Arunachal Pradesh, India

Rath Shishir

Engineering Geology & Geotech Div., NHPC Corporate Office, Sector-33, Faridabad, Haryana, India
E-mail: shishir.rath@gmail.com

The Subansiri Lower HE Project (2000MW), India's largest hydropower project is under construction on river Subansiri at Gerukamukh, India. The project is geologically located on the Siwaliks (Siwalik sandstones), south of the Main Boundary Thrust (MBT). The Himalayan Frontal Thrust (HFT) that separates the Siwaliks from the Indo-Gangetic plain is located further south of the Subansiri Lower HE project.

Initially designed as 116 m high concrete gravity dam, further modifications in dam design especially in the extended spillway and dam foundations have been made as additional safety features of the project. The geological and geotechnical aspects including seismic design parameter criteria (the project falls in seismic zone V), rock strength and slope stability issues have been adequately and appropriately addressed for the construction of this project. The paper deals with geological and geotechnical aspects of the project, design modification with extended spillways, foundation issues and slope stability majors which have been incorporated in the project. Being a large project, adequate geological and geotechnical investigation and technical studies have been carried out at investigation stage. Besides this, geotechnical and geotechnical issues and dam foundation issues have been addressed with additional design majors including upstream and downstream cut-off walls. Slope stability issues including stability of the power house back slope have been taken up with appropriate support measures. Further elaborating, the paper highlights present construction activities and status thereof for implementing the additional safety features in energy dissipation arrangement and dam foundations. An attempt has been made to discuss geological and geo-technical aspects in construction of concrete gravity dams in Himalayas in general and additional arrangements in the Subansiri Lower HE Project in particular.

Levee performance during the 2010–2011 Canterbury earthquake sequence

***Sophie Bainbridge, and Tim McMorran**

Golder Associates, Level 1, 214 Durham Street, Christchurch, New Zealand
**Corresponding author: sbainbridge@golder.co.nz*

In the period between September 2010 and December 2011, Christchurch was shaken by a sequence of strong earthquakes including the M_w 7.1 on September 4, 2010; M_w 6.2 on February 22, 2011; M_w 6.2 on June 13, 2011, and M_w 6.0 on December 23, 2011 earthquakes. The levee network along the Kaiapoi and Avon Rivers suffered extensive damage. This presented an opportunity to document a regional scale case-study of the effects of liquefaction on a levee system.

Data collected following the 4th September 2010 and 22nd February 2011 earthquakes is categorised into seven key deformation modes. For each deformation mode we identified the liquefaction-induced, consequential levee damage and the factors that influence a particular style of deformation. The deformation modes were used to create a severity classification to discriminate the indicators and factors that contribute to major and severe damage from the factors that contribute to all levels of damage. A number of calculated, land damage, levee damage and geomorphological parameters were analysed and compared at 178 locations along the Kaiapoi and the Avon River levee systems.

A critical liquefiable layer was present at every location with relatively consistent geotechnical parameters across the study site. A statistical analysis of the geotechnical factors relating to the critical layer was undertaken in order to find correlations between specific deformation modes and geotechnical factors. It was found that each individual deformation mode involves a complex interplay of factors that are difficult to represent through correlative analysis.

There was, however, sufficient data to derive the key factors that have affected the severity of deformation. It was concluded that levee damage is directly related to the presence of liquefaction in the ground materials beneath the levees, but is not critical in determining the type or severity of damage, instead it is merely the triggering mechanism. Once liquefaction is triggered it is the gravity-induced deformation that causes the damage rather than the shaking duration.

2D numerical analysis using LEM for slope subjected to toe cutting and earthquake: A case study of Bhatwari, Uttarkashi

***Tarun Singh[1], Ankit Singh[2], and K. S. Rao[3]**

[1, 3]Department of Civil Engineering, Indian Institute of Technology Delhi, New Delhi, India
[2]Centre of Studies in Resources Engineering, Indian Institute of Technology Bombay, Powai, India
**Corresponding author: tarun.iitd@outlook.com*

This paper describes the detailed numerical analysis performed to study and observe the effect of toe cutting caused by anthropogenic activities like construction of new roads, widening of existing roads and by natural processes like undercutting and erosion by rivers and streams, on the stability of slopes. For this purpose, a slope showing the evidence of toe cutting caused by river erosion and undercutting is chosen for analysis. The slope selected for analysis is made up of a mixture of soil and debris material lying above the rigid hard bedrock foundation. The selected slope has been analysed using the Morgenstern–Price limit equilibrium method using the GeoStudio SLOPE/W software. In order to comprehend the behaviour of slope under different geotechnical, hydraulic and seismic conditions the analyses have been performed by taking into account a wide variation in these parameters. The behaviour of slope and its probability to failure is calculated on the bases of the evaluated strength reduction factor in different strength effecting conditions. In this study, the analyses were conducted in three different phases. In the first phase, simplified model of the slope was analysed under its own weight without any additional parameter. In the second phase, pseudo static analysis had been performed on the slope. In the third and last phase, hydraulic parameters were incorporated in the slope model and the results were generated. Results of the analysis are presented in easy to interpret graphical format and based on the analysis, results are interpreted for the critical horizontal limit of the vertical toe cutting of the slopes for the different types of slopes having varied geotechnical parameters.

Author Index

A

B

C

D

E

F

G

H

I

J

K

L

M

N

O

P

Q

R

S

T

U

V

W

X

Y

Z

Instructions to Authors

The articles must be sound in scientific contribution not published or submitted for review elsewhere. The **manuscript** should be addressed to the Editor-in-Chief of Nepal Geological Society (E-mail: nktam555@gmail.com) and should not exceed 30 pages in length, including all the text, references, annexes, figures and tables. The paper must be properly edited for spelling errors and typos. The acceptance or rejection of a manuscript is based on appraisal of the paper by two or more reviewers designated by the Editorial Board. Critical review determines the suitability of the paper, and its originality, adequacy and conciseness of the presentation. The manuscripts are returned to the authors for revision or final polish. After the manuscripts have been accepted, the editors may ask authors for final changes if any, must be made at this time, because no galley proofs are sent to authors.

All the manuscripts should be submitted in electronic files in MS Word including title, author(s), affiliation(s), abstract, main text, references, figure and table captions, figures and tables. All the figures and tables (high quality minimum of 300 dpi jpg or pdf) must be submitted in separate individual files indicated by figure or table numbers. Page margins of minimum 1 inch each in all the four sides of the page should be kept. All the text should be in double-spaced and in 12-point Times New Roman, except for a title.

Title
Case should be in 14-point TNR type, without capitalising initial letters of each word unless necessary. The title of the paper should be relevant to the research work.

Name(s) and affiliation(s)
The title will be followed by full author(s) name(s) and affiliation(s) in 12-point TNR type. When there are more than one author, indicate affiliation of each author that should contain full address including the country, and e-mail address, and also indicate corresponding author.

Abstract : should be followed by the heading "ABSTRACT", and should contain less than 250 words in TNR with a 12-point TNR, left margin. The abstract should present information and results in capsule form and should be brief and objective, containing the content, giving the overall scope followed by emphasis on new information and conclusions of the paper.

Keywords : less than seven words; each word with initial letter capitalised.

Illustrations
All the figures (drawings, photographs, charts, etc.) and tables must be submitted in high quality jpg image (minimum of 300 dpi) or pdf. As no correction will be possible to figures and tables submitted, authors will have to prepare them in print-ready forms. **Figures** should be clear and page size-friendly, using distinct lines, font size (8- to 10-pt) and patterns (B/W or colour). Put type labels, or scales directly on the photographs rather than on a separate overlay or in the caption. Use graphic scales instead of verbal scales on illustrations. For colour figures, authors must bear about $50 per colour figure/plate. **Tables** should contain font size of 8- to 9-pt TNR Plain type. Use only three border lines, i.e. one each on upper and below the heading, and one at the bottom of the table. The overall size of the table must be journal's page size-friendly (at one of various setups: quarter, half or full page fitting).

Style
Authors are responsible for providing manuscripts in which approved geological and other scientific terminology is used correctly and which have no grammar or spelling errors. Authors must check for accuracy and consistency in use of capitalisation, spelling, abbreviations, and dates. Figure and table captions should be in 10-pt TNR bold, as shown here: **Fig. 1, Location of study area**; **Table 1: Results of analysis of rock composition**.

Acknowledgements : should be of less than 100 words.

References
All references mentioned in the text, figures, captions, and tables must be listed in the Reference section. Only references cited in the paper (for example: Ollier, 1981; Deoja et al., 1991) are to be listed. For example:

Deoja, B., Dhital, M., Thapa, B., and Wagner, A. (Editors), 1991, *Mountain Risk Engineering Handbook*. International Centre for Integrated Mountain Development, 875 p.

Dikshit, A. M., 1994, Landslide Hazards in Nepal: Causes and Assessment. Water Nepal, v. 2, pp. 2–12.

Joshi, J., Majtan, S., Morita, K., and Omura, H., 2000, Landslide hazard mapping in the Nallu Khola watershed, central Nepal. Jour. Nepal Geol. Soc. v. 21, pp. 21–28.

Ollier, C. D., 1981, *Tectonics and Landforms*. Longman, London, 324 p.

Owen, L. A., Sharma, M. C., and Bigwood, R., 1995, Mass movement hazard in the Garhwal Himalaya: the effects of the 20th October 1991 Garhwal earthquake and the July–August 1992 monsoon season. In: McGregor, D. F. M., Thompson, D. A., (Eds.), *Geomorphology and Land Management in a Changing Environment.* Wiley, Chichester, U.K. pp. 69–88.

Tokuoka, T. and Yoshida, M., 1984, Some characteristics of Siwalik (Churia) Group in Chitwan Dun, Central Nepal. Jour. Nepal Geol. Soc., v.4, (Sp. Issue), pp. 26–55.

Journal of Nepal Geological Society
Registration No. 1/042/043
US Library of Congress Catalogue Card No.: N-E-81-91064
ISSN 0259-1316

Published by: **Nepal Geological Society**
PO Box 231, Kathmandu, Nepal
Email: info@ngs.org.np
Website: http://www.ngs.org.np