Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

HDS06-01 Room:102B Time:May 23 09:00-09:15

On losses from landslides associated with large dams

David Petley[1*]

[1]Durham University, UK

In 1963 the Vajont landslide in Northern Italy slid into a reservoir, generating a displacement wave that killed over 2500 people. Since then there has been a high level of awareness of landslide hazards amongst the engineers of large dams, such that there has been no repeat event on a similar scale. However, landslides continue to generate significant problems at large dam sites and on the banks of the associated reservoirs.

This paper examines the occurrence of landslides associated with dam projects over the last decade. It is demonstrated that reservoir bank failures continue to cause high levels of economic loss, although the loss of life in these events is reasonably low. The most notable case in recent year has occurred along the banks of the Three Gorges reservoir in China, where landslides have occurred at a higher than expected rate, resulting in the need to relocate large numbers of people. However, the data suggest that landslides are a very significant hazard during the construction of large dams. Since 2002 at least 550 lives have been lost in landslide events at or near to the construction sites of large dam projects. Most of these landslides, which have occurred in particular in East and South Asia, are the result of rainfall triggered rock slope collapses and debris flows, although some have occurred as a result of seismic triggering.

This paper examines the spatial and temporal occurrence of these losses and demonstrates that there appears to be an upward trend in the annual number of events. Over the next two decades a very large number of new dam projects are planned in high mountain area, particularly in Asia. This research suggests that a much higher level of attention needs to be paid to landslides during the construction of these large infrastructure projects if total losses over the this period are not to approach those of the original Vajont landslide.

Keywords: landslide, dam, reservoir, debris flow

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HDS06-02 Room:102B Time:May 23 09:15-09:30

Landslides of pumice fall deposits induced by the 2009 Padang earthquake and the formation of halloysite

Maho Nakano[1*], Masahiro Chigira[2], Choun-Sian Lim[3]

[1]Division of Earth and Planetary Science, Graduate School of Science, Kyoto University, [2]Disaster Prevention Research Institute, Kyoto University, [3]Southeast Asia Disaster Prevention Research Institute, Kebangsaan University Malaysia

The 2009 Padang earthquake triggered nearly 1000 landslides which killed at least 600 people, a half of the death toll of the Padang earthquake. We made field investigation and laboratory analyses in order to clarify the mechanism of these landslides.

We investigated Tandikat area where the most destructive landslides with long run out had occurred. Tandikat area is widely covered by pumice fall deposits, which hereafter referred to as the Qhpt, underlain by paleosol. We found that landslide sites have common characteristic features: 1) Landslides occurred in area with Qhpt thicker than 4 m, 2) Sliding surfaces were made in a layer of mixed pumice and paleosol at the base of Qhpt.

From XRD analysis, we find that the pumice-paleosol mixed layer is rich in halloysite, while the underlying paleosol is rich in gibbsite and almost free from halloysite. Upper part of the Qhpt which had not been mixed with paleosol is free from halloysite. Cone penetration tests in the field showed that the pumice-paleosol mixed layer has the smallest resistance.

These evidences suggest that the halloysite rich pumice-paleosol mixed layer was one of the most important geological factors of the earthquake-induced landslides in this area. Halloysite in the paleosol of the mixed layers was probably made by the interaction between gibbsite and dissolved silica from pumice grains in the mixed layers and from percolating groundwater. Halloysite formation in the pumice grains of the mixed layers likely was promoted by the water accumulated on the essentially impervious paleosol.

Keywords: halloysite, the 2009 Padang earthquake, landslide, pumice fall deposits, geohazardz, landslide induced by earthquake

Japan Geoscience Union Meeting 2013
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HDS06-03 Room:102B Time:May 23 09:30-09:45

Landslide Investigation of Earthquake Induced Landslide during Rainfall in Tandikat, West Sumatra, Indonesia

Fikri Faris[1*], Fawu Wang[1]

[1]Shimane University

Indonesia is an archipelagic country which extends on one of the most active seismicity area in the world. In geological perspective, the west and south coast of the archipelago takes apart into Pacific Ring of Fire makes it numerously contains active volcanic mountains which extensively supplies loose volcanic material. The tropical climate brings consequence of high precipitation of the most area. These facts make Indonesia has high vulnerability against geo-disaster which induced by combination of earthquake and rainfall on volcanic areas.

One of the most devastating earthquakes in Indonesia struck West Sumatra Province on September 30, 2009, at 5:16 p.m. with MW 7.6 magnitudes, caused about more than 1000 deaths. The earthquake excited number of landslides which took more than 60% of total earthquake death toll. The most extensive landslides which occurred in Tandikat, Padang Pariaman Regency, buried hundreds of people and flattened some villages (Fig.1). These landslides occurred on loose pumice layered mountain during rainfall. The combination of intensive rainfall and strong earthquake is considered to decreases the slope stability dramatically. This study attempts to reveal contributory factors which involved on the event.

Integrated study of the landslide elaborating field investigation, laboratory work and numerical modelling were conducted. Geological investigation on the landslide area and laboratory investigation had been performed to examine geological features and mechanical properties of sliding material. The field investigation consisted of soil sampling, Standard Penetration Test (SPT), geological logging, in-situ permeability and density test. Further examination about mechanical properties of landslide deposit samples subsequently performed in laboratory. Several static and dynamic tests using cyclic triaxial apparatus had been conducted to study about stress-strain history of the soil under dynamic condition. The mechanical parameters of the material were then derived from both geological investigation and laboratory test by correlating SPT values and taking laboratory tests result. These parameters were then used into numerical model using finite element method software ABAQUS to analyze earthquake effect by considering time-historical acceleration from actual earthquake record.

Field investigation revealed that, particularly in the area, impermeable clay stratum is overlain by porous pumice layer. The difference of permeability may cause the saturation of lower part of the pumice layer when rainfall percolates. Both static and stress-controlled dynamic triaxial test showed the contractive behaviour of pumice deposit. This behaviour brought the consequence of excess pore water pressure increase at small strains. Immediate liquefaction occurred when specimen was conditioned as fully saturated and initial pore water pressure was given as to simulate ground water table after rainfall.

Finite element modelling using ABAQUS software indicated amplification phenomena of earthquake Finite element modelling using ABAQUS software indicated amplification phenomena of earthquake acceleration in the landslide area. The contributing factor of the amplification was the thick clay stratum and weathered andesitic sandstone layer below the pumice material deposit that was considered have low stiffness. Another possibility causing of amplification was the topographical aspect involving sloping surface. The numerical model and laboratory tests clarified that the amplification effect on the area caused the collapse of the pumice material. Immediate liquefaction was considered as the mechanism of the landslide due to the combination of earthquake amplification effect and soil saturation by rainfall during earthquake.

Keywords: Landslide, earthquake, rainfall, cyclic triaxial test, ABAQUS

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HDS06-04 Room:102B Time:May 23 09:45-10:00

Two Cases of Landslide Signal Mining from Massive Earthquake-Induced Landslides

Tien-Chien Chen[1*], Ling-Qi Zhou[2], Wan-Jun Yang[2], Zong-Lian LI[2]

[1]Associate Professor, Soil and Water Conservation, National Ping-Tech, Pingtung, Taiwan, [2]Graduate Student, Soil and Water Conservation, National Ping-Tech, Pingtung, Taiwan

The short-time Fourier transform (STFT) is employed to identify two landslide- induced seismic signals in Chi-Chi earthquake. 7 seismic signals registered by strong ground motion station that contains the ground motion caused by two earthquake -induced landslide, Tsaoling rockslide and Jiufengershan landslide, are studied in the paper. Tsaoling rockslide involved a mass movement of 125 million cubic meters transported a 2 km long was triggered during 1999 Chi-Chi earthquake in central Taiwan. The seismic signal was recorded by the strong motion station about 700 m north of the landslide. 4 strong motion stations are close to landslide within 0.7 to 10 km. The Jiufengershan avalanche was the second largest landslide triggered by the Chi-Chi earthquake, mobilizing about 36 million cubic meters,of rock and soil from a dip slope. The Jiufengershan avalanche transported a 42?65 m thick, 1.5 km long, 3 strong motion stations are surround the landslide within 5 to 8 km.

The study shows that the earthquake signal began with a band of low frequency waves from 0.1 to 20 Hz, and rose up to 40 Hz during the main shock; then, the high frequency decreased progressively from 20 to 10 Hz. For the case of Tsaoling landslide, the landslide seismic signals show a high frequency band up to 60 Hz at the rock block cracking period. And dramatic excitation occurs during the 37.5th to the 41th sec, this period is estimated as the rock block sliding. At last, the high frequency of 30 Hz registered at the 76th sec. which is likely to correspond to the sliding mass impacting on the old debris dam. Next, for the case of Jiufengershan, the main shock appears the frequency spectrum for 0.1 to 40 Hz because of strong ground stations was located very near the faults. However, after main shock period the seismic signal demonstrated a 20 to 40 Hz high frequency band with difference pattern to the earthquake wave.

Results suggest the significant frequency of 20-40 Hz found as in rockmass sliding. It can be distinguished clearly from the after main shock waves which have frequencies of less than 20 Hz, typically ranging between 0.1 Hz and 10 Hz. The high frequency signal will be attenuated highly, especially in vertical direction signals, as the increasing distance from landslide location to seismic station.

Keywords: Landslide signal, seismic wave, earthquake-induced landslide, short-time Fourier transform

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HDS06-05 Room:102B Time:May 23 10:00-10:15

The internal structure and stability of a rockslide dam induced by the 2008 Wenchuan (Mw7.9) earthquake, China

Gonghui Wang[1*]

[1]Research Center on Landslides, Disaster Prevention Research Institute, Kyoto University

The internal structure of landslide dams plays a key role in their stability; however, it has not been much studied, probably due to the difficulty in obtaining information on internal structure in most cases. Here, we examined the shear-wave-velocity structure of a rockslide dam by a surface-wave technique called multichannel analysis of surface waves (MASW). During the 2008 Wenchuan earthquake (Mw7.9), more than 60,000 landslides were triggered and 800 landslide dams formed. Those dams with a high risk of collapse threatened rescue activities, and almost all of the large landslide dams were treated by digging a sluiceway immediately after the earthquake. Although the risk of collapse of many landslide dams was removed or lowered, not all of the countermeasures were based on well controlled methods. To analyze the internal of landslide dams to assist in carrying out reliable countermeasures, we made detailed investigations on some of the dams, and here describe one landslide dam that occurred in the Tianchi area. Grain-size analysis revealed that the displaced landslide materials experienced fragmentation and segregation during the long movement. The shear-wave-velocity profile of the dam revealed that the dam consisted of three facies (carapace, body and basal facies). The boundary between facies is distinct. The body facies had a greater shear-wave velocity (compared to those landside dams that had suffered collapse failure during the construction of a sluiceway), showing that the dam consisted of more densely deposited materials. This kind of dam body had a lower permeability, capable of retarding seepage that triggers collapse failure of the dam body due to piping. Big blocks on the surface also enabled the dam body to have greater resistance to overflow and thus reducing possible collapse failure in the immediate aftermath of overtopping.

Keywords: Landslide dam, 2008 Wenchuan earthquake, internal structure, stability of landslide dam, grain size distribution

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HDS06-06 Room:102B Time:May 23 10:15-10:30

Geological precursors of catastrophic landslides induced by earthquakes

Masahiro Chigira[1*]

[1]Disaster Prevention Research Institute, Kyoto University

Recent earthquakes, the 2011 Tohoku earthquake, the 2009 Padang earthquake, the 2008 Wenchuan earthquake, the 2008 Iwate-Miyagi Inland earthquake, the 2005 northern Pakistan earthquake, and the 2005 Mid Niigata prefecture earthquake, gave us lessons about where and why large, catastrophic landslides are induced by earthquakes: those landslides had specific preparatory processes, mechanical or chemical, to be induced by earthquakes.

The 2011 Tohoku earthquake induced long run out catastrophic landslides in pyroclastic fall deposits with a sliding surface in halloysite-rich paleosol, which once was made by chemical weathering and has been resilified so that gibbsite changed to halloysite. Halloysite is very fragile against shaking and has been a major component of sliding surface materials of landslides during many earthquakes including the 2009 Padang earthquake. Dissolution of carbonate by groundwater was another chemical preparatory process of landslides induced by the 2008 Wenchuan earthquake.

Mechanical preparation for earthquake-induced large landslides is deep-seated gravitational slope deformation, which preceded many landslides involving the Daguanbao landslides by the Wenchuan earthquake and the Chiu-fen-erh-shan and the Tsaoling landslides during the Chi-Chi earthquake. Deep-seated gravitational slope deformation deteriorates rocks, which would become more susceptible to earthquake tremor. River erosion that undercut previous landslides, once collided to the opposite slope, is another important mechanical preparation for the landslides reactivated by earthquakes. There occurred many such catastrophic landslides during the Mid Niigata prefecture earthquake and the northern Pakistan earthquake.

Keywords: landslide, earthquake, pyroclastics, gravitational slope deformation, limestone

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Implementing Triple Helix Concept into DRR: Geospatial Information for Landslide Susceptibility Assestment in Lombok

Yukni Arifianti[1*], Eko Agus Prasetio[2], Jewgenij Torizin[3], Michael Fuchs[3]

[1]Geological Agency of Indonesia, [2]School of Business & Management, Institute of Technology Bandung, [3]BGR, German

The Triple Helix Concept (THC) is an innovation of relationships between 3 elements: Government, Academics, and Business. Disaster Risk Reduction is the concept and practice of reducing disaster risks through systematic efforts to analyse and manage the causal factors of disasters, including through reduced exposure to hazards, lessened vulnerability of people and property, wise management of land and the environment, and improved preparedness for adverse events (UNISDR). DRR is a multifaceted issue requiring involvement from several sectors. Government and universities (academic) took part by establishing the policies, plans and programs, providing expertise in the tools and methodology. Private sector (business) is taking the lead in the term of investments and planning ahead to protect industry and society from disasters, economic disruptions while ensuring business continuity.

Most of the disaster related data are spatial in nature involve some geographic component. For planning, monitoring and decision making; there is typically a need for geospatial data. Therefore, geospatial information could play an important role in susceptibility assessment. The development in Lombok grows rapidly so that human activity will trigger more geological hazards. One of these hazards is landslide. To cope with these hazards impact, study about more detailed geological hazard map, information on the landslide prone areas, and identification of area susceptible to landslide is recommended. There have been many progress made in landslide susceptibility assessment (LSA) studies, whereby much of this progress is based on the extensive use of geospatial information by using GIS (geographical information system) and Remote Sensing technique. It can ease LSA and provides information for DRR missions. It also provides a high efficiency and optimizes time resources. The resulting landslide susceptibility map will be the base for DRR activities on Lombok Island.

Keywords: triple helix, disaster risk reduction, geospatial information, landslide susceptibility assessment, Lombok

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HDS06-08 Room:102B Time:May 23 11:00-11:15

Undrained shear behavior of saturated loess at different concentrations of sodium chlorate solution

Fanyu Zhang[1*], Gonghui Wang[2], Toshitaka Kamai[2], Wenwu Chen[2]

[1]School of Civil Engineering and Mechanics, Lanzhou University, [2]Research Center on Landslides Disaster Prevention Research Institute Kyoto University

A series of ring-shear tests was conducted on saturated loess to investigate the effects of NaCl concentration in pore water and desalinization on the shear behavior under undrained conditions. The loess samples taken from a loess area with frequent occurrence of landslide in China were saturated by de-aired water with different concentrations of NaCl solution, and then were sheared undrained. After that, the samples were retrieved, remoulded, re-set into the shear box, and re-saturated by passing through de-aired distilled water (such that the samples were desalinized), and then were sheared undrained again. Through comparing the undrained shear behavior, the effects of NaCl concentration in the pore-water and desalinization on the undrained shear behavior of loess were examined. The results showed that the variation of NaCl concentration in pore water can strongly affect the shear behavior of saturated loess. Both the peak shear strength and steady-state strength increased with increase of NaCl concentration until a certain value, after which they decreased with further increase of NaCl concentration. Meanwhile, the peak shear strength and steady-state strength of the retrieved samples recovered to those of the original sample, namely the salinization of loess is recoverable. These findings may be of practical importance to better understanding the repeated occurrence of some irrigation-induced loess landslides in China.

Keywords: sodium chlorate solution, loess landslide, undrained shear behavior, irrigation

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HDS06-09 Room:102B Time:May 23 11:15-11:30

The Study on Landslide Disaster Mitigation and Management Using Numerical Analysis in Malaysia

Swee Peng Koay[1*], Habibah LATEH[1], Naoki SAKAI[2], Yuichiro USUDA[2], Suhaimi JAMALUDIN[3], Tomofumi KOYAMA[4]

[1]Universiti Sains Malaysia, [2]National Research Institute for Earth Science and Disaster Prevention, [3]Public Works Department, Malaysia, [4]Kyoto University

In Malaysia, recently, landslides happen occasionally and cause millions of losses every year. Government spends millions of Malaysian Ringgit on monitoring slope and slope failure measurement. NGO works together with local authority to monitor the slope to prevent casualty.

Setting site monitoring system in all slopes, with the extensometer, soil moisture probe, inclinometer and water gauge can monitor the movement of the soil in the slopes and predict the occurrence of slopes failure. However, installation monitoring system, in the whole country, to monitor and predict the failure of the slopes is very costly and almost impossible.

Here, we apply the numerical analysis on factor of safety F to predict the stability of the slope, which considers mechanism of resisting and driving forces in the slope. By comparing the observed data from monitoring site, history data and the result from the simulation using numerical analysis, a graph with a slope failure curve, by the rain data, can be determined. The increment of the accumulated rainfall data crossing the curve indicates the probability of the slope failure. Furthermore, the slope failure curve can also be diverted in the risk areas where have the almost same slope degree and soil properties.

Moreover, in our study, analyzing contour map, DEM data and history data by grading high, medium and low risk is proposed to determine the risk slope areas and narrow down surveying areas from the huge areas to the specified slope areas.

Data and information dissemination, by establishing quick response portal service, hazard map and providing training to the public, will alert the public on the risk of landslides. The awareness on the risk of slope failure among the public and installing the early warning system will minimize the loss due to slope failure.

Keywords: monitoring system, factor of safety, slope degree, soil properties, hazard map, public awareness

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HDS06-10 Room:102B Time:May 23 11:30-11:45

GEOLOGICAL ASSESSMENT AND POTENTIAL DEBRIS FLOW VOLUME ESTIMATION AT BUKIT CHENDERING, KUALA TERENGGANU, TERENGGANU, MAL

Tajul Anuar Jamaluddin[1*], HUSSIN, Hamzah[1], LIM, Choun Sian[1], KOMOO, Ibrahim[1]

[1]SEADPRI, UKM Bangi, Selangor Malaysia

Debris flow geohazard is not uncommon in hilly tropical terrain of Malaysia but received little attention from geoscientists and engineers mainly because their occurrences are difficult to predict. The development of the new Terengganu Palace in the northern flank of the Chendering Hill has been considered to be facing with threat of debris flow geohazards because the palace compound is partly surrounded by steep and rugged hill slopes which are dissected by narrow and steep hanging valleys. The potential for debris flow geohazards in this area has been identified from aerial photographs studies and field mapping, where some of the hanging valley flows are converging towards the site of the Public Ceremonial Building. Evidences for past debris flows have been identified in five hanging valleys. Geological assessments have been carried out in these valleys to search for evidence of past debris flow incidents and to characterise the nature of the past debris flows deposits. From the five hanging valleys, only two (i.e. Valley 2 and Valley 3) are considered very high risk and ought to be installed with suitable mitigating structures. Flexible debris flow barriers rather than rigid concrete structures have been opted for Valley 2 and Valley 3 because of site accessibility and construction feasibility. To facilitate the engineering design of the flexible debris flow barriers, potential debris flow volume for both valleys have to be estimated on the first place. The estimation of the potential debris flow is done empirically by estimating the area of the source and the thickness of the potential source (i.e. the combined thickness of loose sediments, colluvial deposits, and overburden soils). The estimate is done by subdividing the map of the potential source area into equal cells using a grid, estimate the proportion of each cell that is covered by the deposits, and then sum. Thickness (Tm) of the loose sediments at source were measured and estimated directly in the field from the exposed outcrops along the stream channel. With the given area and thickness, volume of the bulk debris flow source can be calculated by multiplying the total area with the measured source thickness (Tm). This formula gives dry volume of debris sources in the valley catchment. Under extreme rainfall event, it is very unlikely that the entire volume of the debris in the catchment will turn into debris flow. Past experiences indicate that the likely situation is that only 20 percent to 30 percent of the debris sources will be sliding down entering the valley channel and mixed up with water to form the likely debris flow volume. In most wet debris flow events of tropical country, the amount of water made up about 40percent of the entire flow volume. Therefore, by taking these factors into consideration, the predicted debris flow volumes for both Valleys 2 and 3 can be reliably estimated to facilitate the engineering design of the debris flow barriers.

Keywords: Debris Flow, Geohazard, Geological Assessment, Volume Estimation, Hilly Tropical Terrain

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HDS06-11 Room:102B Time:May 23 11:45-12:00

RAINFALL PHENOMENON TRIGGERING LANDSLIDE IN INDONESIA

Yunara Dasa Triana[1*], Imam A. Sadisun[2]

[1]Geological Agency of Indonesia, [2]Institute of Technology Bandung

Landslides are common geological disasters in Indonesia, especially during rainy season. Geological conditions, climate, and human activities might cause landslide, however earthquake could trigger landslide but the most common landslide in Indonesia due to heavy rainfall.

Number of landslide commonly increases during rainy season, November - February, as recorded in 2005 to 2012. In 2010, rainfall was high since all the year long rained and the number of landslides higher than previous years. In 2010, landslides attained 199, higher than in 2009 (161), 2008 (139) and 2007 (101) as well as in 2011 (82) and 2012 (124).

A large landslide occurred in Dewata Tea Plantation on February, 23rd 2010, Bandung district, West Java province. It collapsed after high intensity rainfall which reached 675.9 mm during 15 days. Slope stability analysis in this area suggested that heavy rain could reduce the safety factor 22.75% of 1.257 (normal conditions) to be 0.971.

Keywords: landslide, rainfall, Dewata

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HDS06-12 Room:102B Time:May 23 12:00-12:15

The Development of self-potential tomography to estimate the ground water condition

Hiroshi Otsubo[1*], Katsumi Hattori[1], Tomohiro Yamazaki[1], Adrin Tohari[2], Khori Sugianti[2]

[1]Graduate School of Science, Chiba University, [2]LIPI, Indonesia

Landslides are one of the most severe natural disasters in the world and there are two types; rainfall induced landslides and landslides triggered by an earthquake. In this research, basic study on early warning system for landslides will be performed to understand rainfall-induced landslide process by hydrological and electromagnetic changes. The final goal of this research is to develop a simple technology for landslide monitoring/forecasting using self potential method. The advantages of this method are lower cost and easier to set up than the hydrological approaches using pore pressure sensors. The laboratory experiments show that the self-potential variation has relationship with the water and soil displacements. But, we can not estimate the ground water condition by self-potential yet. So, in this study, we developed self-potential tomography to estimate the ground water condition.

Measured self-potential value under the ground and charge distribution to estimate is given by the Coulomb's law. Therefore, this is inverse problem. To solve the inverse problem, we adapt Phillips-Tikhonov regularization with Generalized Cross Validation (GCV). To evaluate the reconstructed charge distribution and investigate the relationship with the ground water condition, computational simulations and applications to practical data by using the sandbox experiment has been examined.

It is found that the developed algorithm is effective through numerical simulations. Results of application to sandbox experiments show good performance but there are some problems to solve.

The details will be given in our presentation.

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HDS06-13 Room:102B Time:May 23 12:15-12:30

The initiation and positive regulation of the catastrophic Siaolin landslide

Che-Ming Yang[1*], Jia Jyun Dong[1]

[1]Graduate Institute of Applied Geology, National Central University, Taiwan (R.O.C.)

The extremely high intensity rainfall of the 2009 Typhoon Morakot triggered numerous landslides in South Taiwan. The Siaolin landslide is the most notorious one where the down slope Siaolin village suffered heavy casualties. The geological characteristics of the Siaolin landslide and the sequence of this catastrophic event have been studied extensively. Even though the kinematics of the Siaolin landslide was depicted quantitatively via numerical simulation, the initiation and mechanisms associated with rapid moving of this landslide is poorly understood. A simplified rigid wedge model is accordingly used to study the initiation of the Siaolin landslide. The north plane of the wedge is assumed the bedding plane overlaid the matrix-supported colluviums whereas the south sliding surface is identified as a high angle fault. Besides, the crown of the Siaolin landslide is set as a tension crack on the eastern side of the wedge. The colluvium and fault gouge were collected from the Siaolin landslide site and a series of low- to high-velocity rotary shear tests was performed. The peak friction angle of the colluvium and the fault gouge are 22.8? and 18.3? under a velocity of 3.3 micron/sec. The factor of safety of the wedge can be calculated using a commercial wedge analysis tool. The result shows the wedge failure happened (FS$<$1) when the average water table attained 96% of the slope height. This result corresponds with the heavy rainfall triggered Siaolin case. Remarkably, the fault gouge, which composed of mainly angular and planar particles, tends to contract during shearing. It implies no normal stress increment provided during sliding and excess pore pressure could be generated. The shear behavior of the fault gouge contributes the positive regulation mechanism and the Siaolin wedge is apt to accelerate after the sliding initiated. Furthermore, the shear tests of the fault gouge and colluvium show the strength dropped substantially after peak under a high shear velocity (1.3 m/sec) condition. The steady state friction angles of the colluvium and fault gouge are 5.7? and 10.5?. With an increasing velocity after the initiation of landsliding triggered by the critical uplift water force, the rapid moving of the Siaolin catastrophic landslide is inevitable.

Keywords: Catastrophic landslide, Low- to high-velocity rotary shear, Friction coefficient, Wedge failure, Excess pore pressure

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HDS06-14 Room:102B Time:May 23 12:30-12:45

A catastrophic rockslide-debris avalanche at Zhaotong, Yunnan, China: description and dynamic analysis

Aiguo Xing[1*], Gonghui Wang[2]

[1]Shanghai Jiao Tong University, [2]DPRI, Kyoto University

At about 6:00 p.m., on 23rd September 1991, a catastrophic rockslide-debris avalanche (volume:18 million cubic meters) occurred in the Touzhai valley approximately 30 km northeast of Zhaotong city in northeast Yunnan, China. The displaced mass travelled over 3.65 km down the valley in only a few minutes and finally part of the debris mass plunged into the Pan River. The landslide filled the valley with basalt debris to an average depth of 40 m. This paper introduces the general site conditions and then discusses the relevant site conditions favorable to form the rock avalanche. Based on field observations and witness interviews, the sequence of the rock avalanche was analyzed, and a detailed characterization from initiation to final deposition was presented. Finally, we use the DAN model to re-construct the dynamics of the rock avalanche.

Keywords: Rockslide, Debris avalanche, Runout behavior, Dynamic modeling

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HDS06-15 Room:102B Time:May 23 14:15-14:30

Movement of a long-runout landslide in deep snow: A case of the Kokugawa landslide in the Joetsu area, Niigata, Japan

Takashi Kimura[1*], Kazuhiro Hatada[1], Kiyoteru Maruyama[1], Tomoyuki Noro[1]

[1]Snow Avalanche and Landslide Research Center, Public Works Research Institute

On 7 March 2012, a snowmelt-induced landslide (hereafter, the Kokugawa landslide) occurred on a gentle slope (10-20 degree) of Higashi-Kubiki Hill, adjacent to the Takada floodplain in the Joetsu area. The displaced mass of the Kokugawa landslide travelled 750 m from the scarp, destroying 11 houses in the process. The landslide occurred in the early snowmelt period, and the site was covered by a 2-m-thick snow layer when the landslide initiated. A major reason for the long runout may have been reduced friction at the snow interface at the base of the displaced mass. To examine this hypothesis, we describe the detailed movements and topographies of the landslide, based on field observations and aerial photography and LiDAR observations. We then discuss how the snow affected the behaviour of the landslide movements.

The site consists of Neogene marine mudstone and Early Pleistocene conglomerate, with the slope surface covered by loose materials (7-8 m thick) composed of old colluvial deposits and spoil materials from gravel extraction in the 1980s. The collapsed slope was 500 m long and 150 m wide, and the volume of the displaced mass was estimated to be 750,000 m3. The apparent friction angle was 9 degree (H/L = 0.15), as low as that of debris flows or extremely large landslides. Thus, the Kokugawa landslide had a significantly longer runout than landslides with an equivalent volume.

Although the outer part of the displaced mass spread out and deposited at the foot of hill, 350-500 m downward of the scarp, the main body of the mass continued to move rapidly (approximately 15 m/h) without spreading out after reaching a flat paddy field (1-3 degree). Snow on the paddy field was pushed by the mass and swelled up several meters above the snow surface level. The swelled snow formed a moraine-like snowpack of 5-20 m width around the mass. The mass including the snowpack reached houses 250 m from the foot of the hill on the morning of 10 March and stopped after destroying them. Repeated measurement of fixed points on the snowpack and the mass revealed that the mass, including the snowpack on the paddy field, gradually spread out over nine days after reaching the houses.

A lateral ridge developed for 180 m along the right side of the mass on the paddy field. At the boundary between the ridge and the snowpack, slickenlines were observed on the flank of the ridge. Neither snow nor mixed sediment/snow layers were found at the base of the ridge, and the ground surface beneath the ridge appeared undisturbed. In contrast, profiles from boring cores and a transverse trench at the centre of the mass showed that a clay layer about 1 m thick in the paddy field was eroded by the mass. Thus, the formation of the lateral ridge could be attributed to the following two mechanisms: lateral confinement by the compacted moraine-like snowpack that developed around the mass, and depression of the centre of the mass caused by the ground surface erosion.

We could not find any distinct evidence to support the hypothesis that reduced friction at the snow interface at the base of the displaced mass was the major reason for the long runout of the Kokugawa landslide. Rather, our results suggest that the long runout was a result of lateral confinement by the compacted moraine-like snowpack. The behaviour of the Kokugawa landslide indicates that snowpack confinement has a major effect on landslide movement. This effect should be taken into account for accurate prediction of landslide runout and related hazard mitigations in heavy snowfall regions.

Keywords: landslide, long-runout, deep snow condition, lateral ridge

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(May 19-24 2013 at Makuhari, Chiba, Japan)

HDS06-16 Room:102B Time:May 23 14:30-14:45

Using LiDAR Derived Digital Terrain Model to Identify Deep Seated Landslides in Mountainous Areas of Taiwan

Ching-Weei Lin[1*], Chih-Ming Tseng[2], Li-Yuan Fei[3]

[1]Department of Earth sciences, National Cheng Kung University, [2]Department of Land Management & Development, Chang Jung Christian University, [3]Central Geological Survey, MOEA, Taiwan

In August 2009, Typhoon Morakot triggered thousands of landslides and debris flows, and more than 600 people were dead or missing, and the economic loss was estimated at hundreds million of USD. Among these landslides, large deep seated landslides are critical and deserve attention, since they are evolve in destructive failures. For example, one deep seated landslide, the Hsiaolin landslide, with an area of about 250 ha, buried the entire village of Hsiaolin in Kaohsiung County causing 397 causalities, the disappearance of 53 others, and buried over 100 houses (Lin et al., 2011: Tsou2011). After the catastrophic Hsiaolin landslide, the recognition of areas where deep seated landslides may occur become a critical issue for landslide hazard mitigation for government and for peoples living in mountain area of Taiwan.

In 2010, Central Geology Survey of Taiwan initiates a project to establish 1 meter resolution LiDAR derived Digital Terrain Model through the island for helping recognition of potential geohazards in mountainous area. LiDAR capability to detect the bare ground elevation data also in forested areas, it was possible to recognize in detail landslide features also in remote regions difficult to access. In this paper we illustrate the high resolution LiDAR DEM is a very powerful tool to identify deep seated landslides in forest area comparing to the traditional interpretation technique by using stereo aerial photos.

According to landslide features such as arcuate crown escarpments, trenches, multiple ridges, down slope scarps, up slope scarps, transverse scarps, over hundreds of deep seated landslides with an area larger than 10 ha have been recognized in last two years by using inclination shading images and slope maps constructing from 1 m mesh Digital Elevation Model (DEM). Among these landslides, over 40 landslides were confirmed and investigated in the field. In this study, some of field examples are used to illustrate the efficiency of using LiDAR derived DEM in study of deep seated landslides in heavy forest areas.

Keywords: LiDAR, deep seated landslide, digital terrain model

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Large scale gravitational slope deformation related to fluvial dissection of a paleosurface

Ching-Ying Tsou[1*], Masahiro Chigira[1], Yuki Matsushi[1], Su-Chin Chen[2]

[1]Disaster Prevention Research Institute, Kyoto University, Uji, Japan, [2]Department of Soil and Water Conservation, National Chung Hsing University, Taichung, Taiwan

Understanding the processes that lead to gravitational slope deformation and subsequent landslides can provide information about evolving landscapes. In order to shed lights on this topic, we conduct analyses of landscape by geological and geomorphological field investigations, DEM analysis, high-resolution satellite imagery interpretation in the upstream Dahan River and the Chishan River catchments in tectonically active mountain range in Taiwan. We completed inventory of gravitational slope deformation. Mapping was performed by visual interpretation of high-resolution images and/or field investigations and based on precursory topographic features. The precursory topographic features include scarplet or landslide scarp and hummocky surface. The distribution of the gravitational slope deformations shows that most of the gravitational slope deformations occur on slopes at or above the convex slope breaks bounding rims of low-relief paleosurface remnants in high altitudes. The analysis of longitudinal river profile shows knickpoint cluster at the edge of the low relief remnants, indicating the low-relief paleosurfaces have been eroded by retreating of knickpoints in relation to river rejuvenation in response to base-level lowering associated with tectonic uplift of the areas. Corresponding to the incision, the low-relief paleosurfaces can tend to gravitational unstable by undercutting and destabilizing the toes of adjacent hillslopes. Some of these unstable slopes led to catastrophic deep-seated landslides during heavy rainstorms with significant volume of landslide masses, shaping landscape relief. Mass rock creep structures within the source areas of the landslides evident the long-term slope development. Besides, these larger landslides are more effective in high altitudinal zone. This suggests that the larger landslide, which might be controlled by the local relief, is one of the major geomorphic processes for the long-term landscape evolution in tectonically active mountains. We include also chronological development of the landscape in the upstream Dahan River catchment. The results might be useful for future simulation of knickpoint propagation and its effects on paleosurface dissection and for quantitative assessment of landslide hazard disaster mitigation.

Keywords: gravitational slope deformation, fluvial dissection, paleosurface

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Formative conditions of incipient sliding zones in pelitic schist

Shintaro Yamasaki[1*], Masahiro Chigira[2], Dave Petley[3]

[1]Kitami Institute of Technology, [2]Disaster Prevention Research Institute, Kyoto University, [3]Durham University

Large landslides frequently occur in pelitic schist areas, with the structure of the failing mass often being separated into smaller blocks. However, the reasons why landslides occur so readily in pelitic schist, and why their morphology separates into minor blocks, are not clear.

The texture of pelitic schist is strongly anisotropic, which means that it typically has low strength. In addition, landslides commonly occur on dip slopes in pelitic schist areas. These facts suggest that preferable conditions for landslide are related to schistosity within the pelitic schist.

In order to clarify the ways in which the mechanical behavior of pelitic schist controls landslide occurrence, we analyzed the microscopic texture and composition of pelitic schist, and then directly measured the shear behavior of analog materials of pelitic schist using a direct shear machine. Pelitic schist consists of alternating thin black layers, abundant in pyrite and graphite grains, and quartz-rich layers. The black layers are typically weaker than the quartz-rich layers, as has been tested using an Equotip rebound tester. Relatively thick, continuous black layers were found to have low hardness values. So unevenly distributed graphite layers are likely to determine the potential location of microscopic slip in a rock mass. To investigate the behavior of these systems we generated analog materials formed from layers made of artificial graphite sheets, to simulate the black layers, and plaster of Paris to simulate the quartz-rich layers. These systems were sheared parallel to the graphite layer at a constant rate in the direct shear machine at Durham University, allowing measurement of the shear strength. The results suggest that both the peak and the residual frictional strength between a graphite sheet and the plaster surface were about half of the strength of a joint within the plaster. Analog materials having continuous graphite sheets failed at a low shear strength. These results suggest that graphite layers likely reduce strength of the rock, and continuous graphite layers are likely important to determine slips in the rock mass.

Keywords: Landslide, Deep-Seated Gravitational Slope Deformations, Pelitic schist, Sliding zones of landslide, Graphite