Hazard mapping of earthquake-induced landslides of pyroclastic fall deposits

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Earthquake-induced landslides of pyroclastic fall deposits are special because they occur on gentle slopes and are highly mobile with long runout distance; even one landslide could have hundreds of fatalities when it occurs in a populated area. We have been examining such landslides induced by 6 earthquakes in Japan and one in Indonesia with field surveys, and here summarize their geological features to establish a methodology of their hazard mapping. Those landslides were induced by the 1923 Kanto earthquake, 1949 Imaichi earthquake, 1968 Tokachi-Oki earthquake, 1978 Izu-Oshima-Kinkai earthquake, 1984 Naganoken-Seibu earthquake, 2011 Tohoku earthquake, and 2009 Padang earthquake, Indonesia. These case histories strongly suggest that pumice deposits and a clay mineral, halloysite, are very susceptible to earthquake shaking. Stratigraphic horizons of sliding zones of previous earthquake-induced landslides of pyroclastic fall deposits are mostly specified for the cases we studied, so their distribution would be the first criteria for the hazard mapping of this type of landslide. Landslides of pyroclastic fall deposits have occurred repeatedly by earthquakes in a certain area until unstable beds are removed, so we need to consider the potential of earthquake-induced landslide is high in an area with buried pumice fall deposits at least where previous earthquakes induced such type of landslides. Another important factor of potential landslide sites is undercutting of pyroclastic fall deposits with mantle bedding. Undercutting could occur by natural erosion as well as artificial cutting, so its condition would change and make new unstable slopes against earthquake shaking.

Keywords: Pyroclastic fall deposits, Landslide, Earthquake, Hazard mapping

Post shear behavior of pyroclastic fall deposits and landsliding phenomena during the 1949 Imaichi earthquake

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Landsliding phenomena occurring on pyroclastic fall deposits during earthquake had been widely reported. Some of them are in small scale but very catastrophic due to their rapid post failure movement. For example, the Hanokidaira landslide triggered by the 2011 Tohoku earthquake had replaced the debris of about 100, 000 m^3 and killed 13 people. The 1949 the Imaichi earthquake with a magnitude of 6.4 had also triggered more than 80 landslides (Morimoto, 1951), resulting great damages to local properties and lives. However, the initiation and movement mechanism of such kind of catastrophic landslides had not been fully understood. In this study, we surveyed some typical landslides triggered by the 1949 Imaichi earthquake, and examined the geological features of these landslides. We also took samples from the field and kept them in natural moisture state by putting them in plastic bags. We sheared them in both natural moisture state and fully saturated state under undrained or natural drained condition. We did not dry the sample in all the tests to avoid the possible change in clay mineral (halloysite). Our test results showed that all these samples had their residual shear resistance lowering to a very small value with progress of shearing after failure, indicating that the landslide occurring on this kind of pyroclastic fall deposits can suffer from rapid movement. The lower permeability of the sample retarded the dissipation of high excess pore-water pressure generated with the shear zone and then would enable the long runout of the displaced materials. The initiation process of the samples also indicated that strong ground motion during the earthquake would be the prerequisite and the strong ground motion might have resulted from the nonlinear site response features of unsaturated soil layers.

Keywords: earthquake, fluidized landslide, tephra, pumice

Revisit the classical Newmark displacement method for earthquake-induced wedge slide

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Newmark displacement method has been widely used to study the earthquake-induced landslides and adopted to explore the initiation and kinematics of catastrophic planar failure in recent years. However, surprisingly few researchers utilize the Newmark displacement method to study the earthquake-induced wedge slide. The classical Newmark displacement method for earthquake-induced wedge sliding assumed the wedge is rigid and the vertical acceleration, as well as the horizontal acceleration perpendicular to the sliding direction, is neglected. Moreover, the friction coefficients on the weak planes are assumed as unchanged during sliding. The purpose of this study is to test the reasonableness of the aforementioned assumptions. We design the geometry of the wedge and input the synthetic seismicity to trigger the wedge slide. This study uses Newmark displacement method to evaluate the influence for neglecting the vertical acceleration of ground motion firstly. This study uses Newmark displacement method incorporating the rigid wedge method (RWM) and maximum shear stress method (MSSM) to evaluate the influence of wedge deformation. The influences for neglecting the horizontal (perpendicular to the sliding direction) acceleration that incorporating RWM and MSSM are both assessed. In addition, the effects of asymmetric wedges incorporating RWM are also evaluated for neglecting the horizontal (perpendicular to the sliding direction) acceleration. Besides, this research incorporates the velocity-displacement dependent friction law in the analysis to evaluate the influence of constant friction coefficient assumption. Results of this study illustrated that the aforementioned assumptions have significant effects on the calculated permanent displacement, moving speed, and failure initiation. To conclude, this study provides new insights on the initiation and kinematics of an earthquake induced wedge slide.

Keywords: earthquake-induced landslide, wedge slide, Newmark displacement method, rigid wedge method and maximum shear stress method, velocity-displacement dependent friction law

Temporal changes in debris flow characteristics and topography in a debris-flow initiation zone in Ohya landslide, Japan

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Understanding of the debris flow behavior in the initiation zone is essential for the development of mitigative measures, such as warning systems and structures. Volume and surface topography of sediment storage in the initiation zones change with time affected by the sediment supply from hillslopes as well as the evacuation of sediment by occurrence of debris flows. However, influences of such changes on characteristics of the debris flow are not well understood because of a lack of field data. To clarify interactions between accumulation conditions of sediment storage and debris flow characteristics in the initiation zone, we conducted field observations in the Ohya landslide, central Japan, using video cameras and water pressure sensors. We also analyzed DEMs obtained by TLS (Territorial Laser Scanning, 12 periods) and airborne LiDAR (Light Detection and Ranging). Comparison of slope gradient maps calculated from DEMs with different resolutions (from 0.1 to 10 m) showed that 5 m is the best grid size to extract typical geomorphic units, such as rock slopes, talus slopes, and channels. Areas of talus slopes and channels were larger and gradient of channel was steeper when total volume of storage was higher. Flows that monitored by our video-camera system could be classified as either flows comprising mainly muddy water, or flows comprising mainly cobbles and boulders. Flows comprising mainly muddy water are turbulent and are characterized by black surfaces due to high concentrations of silty shale, whereas muddy water is almost absent at the surface of flows comprising mainly cobbles and boulders. The former flow is considered as fully saturated debris flow which can travel on gentler channels, while the latter flow is considered as partly saturated debris flow which is typical on steep channels. The former flow was predominant phase of the debris flow when only small volume of storage existed in the initiation zone, while the latter flow was predominant phase when volume of storage was large. Thus type of flow is likely affected by volume of channel deposits.

Keywords: debris flow, TLS, airborne LiDAR

Past and modern landslides controlled by lithology and geologic structures of accretionary complexes in eastern Kii Peninsula, central Japan

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The relationship between large landslides and geologic characters of accretionary complexes were examined in the Chichibu belt on the eastern part of the Kii Peninsula, central Japan. The rocks in this area consist of Jurassic accretionary complexes composed of basalt, limestone, chert, Permian–Triassic boundary siliceous shale (PTBS), mudstone, sandstone, and mélanges with sheared shale matrices. We examined prehistoric landslides (the Karako, Sono, Kasagi, and Aso landslides), and the modern Kasugadani landslide that was triggered by the Typhoon Meari on 29–30 September 2004. Although the age of the Sono landslide was estimated at 20,440 ±70 BP and 20,820 ±70 BP based on AMS-^{14}C ages of wood fragments embedded in the dammed lake sediments, the ages of other prehistoric slides are unknown. All of the landslides occurred on dip slopes. The bedding, foliation, and fault planes of the rocks in the area generally trend E–W and dip to the north, although those in the Kasugadani area dip to the south as a result of local folding. The landslides selectively slid along the planes of 1) PTBS horizons that were less strong than those of underlying chert, 2) lithologic boundaries with physical contrasts, or 3) boundary faults between mélange units. These geologic structures, including the north-dipping bedding/cleavage/fault planes, were formed during Jurassic subduction–accretion and later uplift processes. The movement directions estimated for the 269 landslides and unstable slopes in this region are also N–NNE, and their slip planes are subparallel to the general bedding/cleavage planes in this area. Thus, future slides are also likely to occur on north-facing slopes.

Keywords: landslide, geologic structure, accretionary complex

River incision, climate change, and bedrock landslides in a high-relief mountainous landscape in Japanese Alps

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The present study attempts to reveal role of long-term river incision and climate change in triggering deep-seated bedrock landslides and thus shaping high-relief mountainous landscapes in a tectonically active region. We curried out GIS(Geographic Information Systems)-based analysis of a 10 m mesh DEM (Digital Elevation Model) and dating of paleo bedrock landslides using TCN (Terrestrial Cosmogenic Nuclide) in Japanese Alps. The topographic analysis revealed long-sectional shape of hillslopes, which is statistically steeper at lowest parts reflecting active undercutting by river incision. The spatial distribution of hillslope angles accords with the output of a simple stability model for bedrock landsliding with a set of parameters of weak rock-mass shear strength. This results imply that river incision and bedrock landslides maintain a quasi-dynamic-equilibrium state of topography with accompanying slope break on hillslopes. Samples for exposure dating were collected from top of boulders on landslide deposits or bare rock slip surfaces. Effect of snow shielding on nuclide production were corrected, and calibrated by radiocarbon dating for some deposits yielded by the identical landslide event. The ages of landslide deposits concentrated in Holocene especially at just after the transition from the last glacial to present interglacial era, and also recent period during the last 3 kyr. These results imply that climate change has potentially instigated the occurrence of bedrock landslides and thus contributed to form and maintain bedrock dominated topography in high-relief mountainous ranges with steep hillslopes adjacent to incised valleys.

Keywords: deep-seated bedrock landslide, slope break, terrestrial cosmogenic nuclide, glacial-interglacial cycles, quasi-dynamic-equilibrium

An investigation on self-potential variation and seismic signals caused by sliding of laboratory scale model slopes

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This study monitored the self-potential variation and seismic signals during sliding experiments for laboratory scale model slopes when the slopes subject to rainfall and groundwater level increasing. The sensors installed including non-polarized electrodes, accelerometers, pore water pressure gauges, and water content gauges for data collection. The results show that the self-potential variation can be used qualitatively to indicate groundwater condition and movement of the sliding body of the model slopes. The seismic signals caused by the three types of sliding processes of the model slopes, including single sliding, multiple sliding and successive sliding, can be easily identified. In addition, the frequency content and time-frequency spectra of the three sliding processes were calculated and compared. We also found that the amplitude and high frequency portion of the seismic signals were attenuated for the case of a model dip slope with a weak clay layer.

Keywords: landslide, slope, seismic signal, self-potential, model test

Detecting and measuring catastrophic landslides using seismology

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Massive, rapidly accelerating landslides generate surface waves detectable on seismometers many 100s of kilometers distant. Time-series single-force inversion of the long-period phases allows approximate reconstruction of the progressive unloading and reloading of the solid earth below the sliding mass. We thus obtain the dynamics of bulk landslide motion and its location. The bulk 3d momentum vector approximates the mass-scaled evolving velocity; by assuming constant mass for the main phase of acceleration and deceleration we can infer a mass-scaled runout trajectory; calibration against satellite imaging of mass-center displacement leads to an estimate of landslide mass. We have developed and applied this methodology to the global detection of >10Mt landslides on a near-real-time basis for several years, and the inventory of such events leads us to make several important conclusions: (1) several such massive landslides go unreported each year; (2) the majority of unreported events take place in SE Alaska and the Himalayas-Karakoram; (3) only supraglacial landslides exhibit long-runout; (4) supraglacial landsliding is a significant and underestimated player in the erosion of glaciated landscapes; (5) on rare occasions, a teleseismically detectable landslide triggers a tsunami, and the precise timing, location and dynamics gleaned from single-force inversion provides an exciting new constraint on tsunami physics.

Keywords: landslide, seismology, tsunami

Stick-slip Motion Preceding a Landslide

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The characteristics of seismic signals generated by the mass movement are considered to reflect the property of the sliding surface, and the use of seismic data for landslide study attracts more attention recently. In the meantime, scientists seek for precursory signals before the large failure of landslides in the seismic data. Here we analyzed the seismic data associated with 2015 Rausu landslide, and found intermittent tremors before the substantial mass movement.
The Rausu landslide started moving before 6:30 on April 24 based on the eyewitnesses, and the large deformation occurred between 11:30 and 16:30 on the day (see the Figure). The size of the landslide is about 380 times 260 m, and the sliding distance is 10-20 m with the rotation of 8 degrees clockwise. The coastal seafloor uplifted and emerged above the level of high-tide due to the buckling of the layers at the toe of the landslide.
A seismogram near the Rausu landslide recorded curious intermittent tremors one day before the substantial mass movement. Each tremor has almost identical waveforms, and the amplitude increases linearly as a function of time. The tremors continued about 20 hours, and on the next day, a large deformation was observed.
This tremor sequence is an evidence of the stick-slip movement of the landslide before the large failure occurs. The identical waveforms suggest that the source location and mechanism are very similar in the sequence, which indicates the tremors are generated at a particular small area. The amplitude and interval of the tremors may reflect the physical properties of the slip surface. The constant interval of the tremor occurrence suggests that the shear stress accumulation was very stable at the precursory creeping stage. This is the first observation suggesting that the heterogeneous structure such as asperities on the slip surface play an important role to control the movement of landslide, and adding a new aspect on the conventional understanding of the mechanism to control the mass movement.

Analysis of seismic waves excited by landslides - a case for Izu-Oshima Island on Oct. 16, 2013 -

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Records of ground motions due to landslides had been observed frequently thanks to the enhancement of the recent seismic network (e. g. Yamada et al., 2012; Ogiso and Yomogida, 2015). These records may enble us to estimate locations and timing of landslides which are especially important to understand the mechanism of landslides in association with geology, hydrological environment and precipitation distribution.
On Oct. 16, 2013, large-scale landslides took place due to extreme rainfall in Izu-Oshima Island in Japan. Accompanied with the Izu-oshima landslide disasters, seismic waveform records which recorded landslide signals were obtained at more than ten stations operated by Oshima Volcano Observatory of ERI, U. Tokyo. Using these waveform records, this study shows the effectiveness and limits to estimate the spatio-temporal distribution of the shallow landslides.
We detected at least 95 landslide events in the seismograms. Particle motions obtained with narrow (2-3 Hz) bandpass-filtered seismic waveforms showed that the Rayleigh waves were dominant at a certain time window. Therefore, assuming the observed waves as surface waves, the movement of the source regions was estimated using spectral amplitude ratios among stations. It was found that the source regions were determined with a small error radius at the earlier stage of one event, though the source regions at the latter stage were limited only in the slope-strike direction. This fact was considered to be due to the spreading of the regions where seismic energies were radiated.
The locations in the slope-strike direction for the detected landslide events were firstly situated mainly in the northern regions of the failure region at 2:00, then moved to the south with increasing frequency around 3:00-4:00, and then terminated past 5:00. The first large-amplitude event occurred only after one event, which suggested that large-scale failures suddenly might have occurred without small failures.
Geological map (Kawanabe, 1998) shows that the orthopyroxene-augite basalt scoria and spatter involved in the eruption in the 14th century cover the top side of the northern failure slope, within which the slip surface was observed (Terajima et al., 2014). On the other hand, the southern failure slope is also covered by basalt scoria but scoria involved in 14th century eruption did not reach there. Therefore, we suggested that one reason for the occurrence time difference in landslide events in the northern and southern slopes was geology difference.
Acknowledgments: We used the meteorological data recorded by JMA.

Experimental investigation on the frictional behavior of granular materials: Implications for better understanding landslide mobility

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The frictional properties of granular materials provide fundamental insights into geophysical processes such as landsliding and earthquake faulting. Some previous experimental studies have shown that the mineralogy of constituent materials plays a first-order control on the transitions of mechanical behaviors, including sliding stability or instability. Moreover, other laboratory investigations have demonstrated the importance of shear rate as a primary control on the strength properties, leading to rate-strengthening or rate-weakening. Despite these efforts, however, neither the knowledge of general relationships among mechanical conditions, material properties and frictional behavior nor the underlying processes are well understood. Here we report on a suite of ring-shear experiments designed to investigate the influence of grain interfaces on the granular frictional behavior over a wide range of shear rates. Samples, consisting of granular halite and mixtures of granular halite and silica sand, were sheared at room temperature and constant normal stress of 400 kPa, and we varied the proportions of halite by weight. The same loading procedures were adopted during each experiment, and the acoustic emissions (AEs) were monitored with a sampling rate of 1.0 MHz. We found that: (1) the pure halite sample shows stick-slip instability, but the pure silica sand sample exhibits stable-sliding; (2) inclusion a low concentration of halite is strongly to modify the frictional behavior and specifically to reduce its ability to sustain stable-sliding for silica sand sample; (3) the stress drop and recurrence time of instability events increase with increasing halite contents, but the occurrence of plastic deformation increases the recurrence time. Ultimately, we discussed the related energy dissipation process considering the released acoustic energy to evaluate the landslide mobility.

Keywords: frictional behavior, acoustic emission, shear rate, landslide mobility, halite

Seismic response on valley fill slope in urban residential region

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Both earthquake ground motion and pore water pressure observations in valley fill were conducted in the southwestern Tokyo, and central Yokohama region. The difference in the earthquake ground motion between records on the both observatories varied with earthquakes. The non-linear response of excess pore water pressure in valley fill was observed during the strong earthquake. These basic information will be valuable for discussing on prediction of valley fills type landslides induced by strong seismic motion in urban region.Earthquake in 5th May 2014 (M6.0) induced strong seismic intensity 5 in central Tokyo (largest earthquake after 3.11). The response 45-60cm/s/s of horizontal motion of soft valley fill less than response on the original ground indicate the “self-dumping effect” of valley fill. In contrast, the response amplified 120-150cm/s/s of horizontal motion, and large UD component of the motion of ordinary valley fill will be caused by amplification of SP trans-wave in unsaturated near surface soil layer. Excess pore pressure increased rapidly after the S peak stage (response to the plastic deformation). Excess pore pressure and barometric pressure changes was opposite in phase before the S peak stage, however, changes of barometric pressure synchronized to the UD displacement changes. So-called “microphone effect”, barometric pressure changes amplified by the UD displacement, was observed in this earthquake.Inclinometer response indicates the movements of the valley fill, and the direction of inclination turns during seismic motion. During the P wave stage, the inclination in ground (G.L. -2, -5,-8m) is small and isotropic. During the 2nd stage (P-S wave), the movement of transvers direction of valley was observed. And, the movement of longitudinal direction of valley was observed at the 3rd stage (S wave). These processes indicate that the friction reduction along the side-wall of valley fill by rolling movement at the P-S wave stage should be prior to the plastic deformation & excess pore water pressure rising during the S wave stage. And, movement along longitudinal valley axis after the peak S wave stage will be possible after the friction reduction in the previous stage. Thus, the friction reduction of side walls will be key process of landslide of urban residential valley fill.

Keywords: Valley fills, Strong seismic motion, Urban landslides

Best Practices for Ongoing Improvement of LIDIA

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Landslide Inventory Database Indonesia (LIDIA) is a database application for landslide inventory. It aims to provide a framework and tools for displaying and analyzing landslide information in Indonesia. LIDIA is a tool to quantitatively assess hazards, systematically manages the diverse and detailed information, and improve the quality of Landslide Susceptibility Assessment (LSA). It was developed in 2011, as a part of inhouse development of the Federal Institute for Geosciences and Natural Resources (BGR), Germany and were tested within the Georisk Project and Geological Agency of Indonesia (GAI). In 2012, LIDIA was translated from english to Bahasa. It becomes a user friendly database software, specially for local goverment. Up to 2016, LIDIA has stored more 5000 landslide events. The information in the database updated on an ongoing basis. For best practices, GAI requires additional database functionality to develpved a pratical and effective approach for LSA and disaster risk reduction. A WebGIS information and an android platform on landslides inventory considerably to be the next improvement. It will provide fixed, reliable and up-to-date information on landslide in Indonesia.

Keywords: Landslide, LIDIA, Database, Inventory

Landslide mapping using AW3D 2m DEM: a case study in Tegucigalpa, Honduras

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In 1998, Tegucigalpa, the capital of the Republic of Honduras, suffered heavy damages by landslides induced by Hurricane Mitch. We have conducted the project of landslide mapping and susceptibility evaluation to reduce landslide disasters as a contribution of the work carried out by the Japan International Cooperation Agency (JICA) since 2015. In this project, we used digital air-photographs taken by JICA and high resolution DEM (Digital Elevation Model) generated by NTT Data and RESTEC (Remote Sensing Technology Center of Japan) using Digital Globe imagery. These data enabled us to create a detailed landslide distribution map to compare with the previous map that used 1:50,000 Honduran topographic data as base map. In the presentation, we will introduce the result of landslide mapping and explain the advantage of using the high-resolution AW3D 2m DEM.

Keywords: Landslide distribution map, AW3D, Tegucigalpa

Detection of the 2015 Gorkha earthquake-induced landslide surface deformation in Sunkoshi River watershed, Nepal using InSAR images

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On August 2, 2014, Sunkoshi river was blocked by the large landslide near Jure village. At 2km downstream Jure, slight displacement on the slope was interpreted by InSAR (Synthetic Aperture Radar interferometry) image. According to field survey the displacement was surely identified and it was triggered by the 2015 Gorkha earthauake, according to local residents. InSAR image was produced from ALOS-2/PALSAR-2 (Phased Array type L-band SAR) data, which were observed on Feb 21, 2015 (before the earthquake) and on May 2, 2015 (after the earthquake). In producing InSAR image, RINC 0.47 software (Ozawa 2014) was used. Path and frame of the PALSAR-2 data is 156 and 550, respectively, and observation mode is Stripmap Fine [10m] mode. To remove the effect of topography from InSAR data, I used SRTM DEM (Digital Elevation Model) in 90 m resolution, but in processing InSAR image, DEM spacing were resampled finer in 45-m resolution. According to the field survey debris were push out from the slope (Photo 1a), and some cracks were identified near the top of the displaced slope, as shown in Photo 1b. The amount of the deformation was measured at ca.10cm, in the site (Photo 1b), and according to interpretation of InSAR image, deformation amount along satellite line of sight was estimated as less than 12cm toward southwest. Therefore, it is thought that both amounts were harmonized; further effort of noise reduction, e.g., finer resolution of DEM will be used. PALSAR-2 data used in this study were provided by JAXA in the framework of special collaborative research (B) “Surface deformation study using a new generation SAR” by Earthquake Research Institute, the University of Tokyo. This study was also supported by "the Nepal Earthquake and Hazard Mapping of Future Landslides for Making the Plan of Better Reconstruction” (Principal investigator, Prof. Chigira) related to the April 2015 Nepal earthquake in the J-RAPID Program by Japan Science and Technology Agency (JST).

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Keywords: landslide, earthquake, Nepal, Gorkha, Synthetic Aperture Radar

Landslide mapping in Nepal: the impacts of the 2015 Gorkha earthquake and the subsequent monsoon

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The Gorkha earthquake (M 7.8) on 25 April 2015 and later aftershocks strongly hit the central part of Nepal and induced numerous numbers of landslides. The Japan Government requested rapid and frequent advice from the Japan Landslide Society in collaboration with Ministry of Land, Infrastructure, Transport and Tourism, Japan and a team supported by J-Rapid of JST on the impacts of the earthquake-induced landslides. As a first step to underpin the advice, the members utilized optical satellite images provided by archive of Digital Globe Co. Ltd., Google Earth, JAXA, and NASA to produce landslide inventory with mapped landslides as polygons. The type of landslides included in this inventory were disrupted rock and debris slides, rockfalls, and debris avalanches and they are either newly formed landslides or enlarged old landslides. The inventory was verified through limited field check in corporation with researchers in Nepal in the catchments of Trisuli River and Bhote Kosi River. We mapped 3594 landslides and significant landslide concentrations were highest to the east of the epicenter (in Gorkha, Dhading, Nuwakot, Rasuwa, Sindhupalchok and Dolakha districts) than to the west. The field survey suggested majority of landslides tend to occur along the slope break that confined the fluvially debuttressed steep valley slopes (>35°) and steep scarp slopes (>35°), which are located against the direction of the dip of the strata, of mountain ridges. These suggest that the landslide distribution might be controlled by fault rupture direction and topographic and litho-structural conditions.
The field survey in late October 2015 after the monsoon season also allowed the observation of development of new landslides as well as the reactivation of pre-existing landslides prompted by the subsequent rainfall. Some newer head scarps tend to develop retreating upward from pre-existing landslide scarps formed in weathered or the earthquake loosen rocks of about 10-20 m in thickness. In addition, a rainfall-induced debris flow was observed with debris served from a debris avalanche in the upper slope which transported into a gully eroding gully deposits.
We are now working on verification of the inventory sine the existing inventory was created by different persons. The results are being used as based data for further hazard evaluation and shared with the government of Nepal.
*The research work of the Japan Landslide Society and J-Rapid are supported by Japan Science and Technology Agency.

Keywords: Gorkha earthquake, Nepal, landslide

Relationship of local precipitation on the landslides over Nepal

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Nepal is a mountainous country located between the Indian and Himalayan tectonic plates. In such a country, landslides represent a major constraint on development. Hence, various statistics related to the landslides are reported by local researchers as well as some international researchers. However, meteorological data over Nepal is not completely opened, so that relationship between local precipitation and the landslides are few. Since landslides occur by many factors in addition to precipitation (e.g. earthquake, soil wetness), it is important to clarify the background relationship between Nepali precipitation and landslides there.
We are investigating the relationship between precipitation, landslides and landslide fatalities using various sources. Regarding precipitation, we are developing APHRODITE-type rain-gauge based precipitation for the earthquake year 2015. While, here we show a preliminary result of APHRODITE precipitation over Nepal on 0.05 degree and landslide fatalities. Landslide and its fatalities data are based on Petley et al. (2007, Nat Hazards) and Disaster review (2014) issued by Ministry of Irrigation of Government of Nepal. The country-summed loss of lives by landslides are compared with APHRODITE's high-resolution gridded precipitation over Nepal.
The result shows Nepali's local monsoon precipitation (June- September) shows significant positive correlation over the western most part of Nepal, the central and eastern part of Nepal. On the contrary, a part of the western part of Nepal and the easternmost part of Nepal showed weak negative correlations. The Kathmandu area does not show a significant correlation. Since the disaster statistics are based on country-wide average, we need to further investigation between the local precipitation and the local landslides including floods. Further, after assembling the local precipitation data over 2015, we will show the precipitation condition before/after the earthquake in April 2015.

Keywords: APHRODITE precipitation, Nepal, Earthquake

Landslide Hazard and Risk Zonation of Chamba Valley in Himachal Pradesh, India

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Being located in the fragile Himalayan regions of Himachal Pradesh, Chamba is highly susceptible to landslides and mass wasting. Frequent landslides pose not just a risk to lives and properties of places in and around Chamba, but also block vehicular traffic and communication channels in and out of an already inaccessible area. However, most disaster management measure focus on post-disaster relief operations and hazard mitigation. To provide a more holistic support to the local population, it is important that preparedness at the level of pre-disaster planning is needed. This can be done by first identifying the regions in Chamba Valley that are most vulnerable to Landslide. The present study is an attempt to identify such areas by preparing a Risk and Vulnerability map of Chamba Valley. To obtain the land use classes Landsat 8 images will be used and Cartosat DEM will be used to create the slope, aspect and hillshade layers. In this work, a Risk Zonation map of Chamba will be prepared by overlaying maps of high population concentration, major transport networks, past Landslide events, and Digital Elevation Model.

Keywords: Vulnerability, Landslide, Digital Elevation Model, Risk Zonation

Effects of active fault types on earthquake-induced deep-seated landslides

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We collected documents on historical earthquake-induced deep-seated landslides (DSLs) published by the Japan Landslide Society and active faults from the digital active fault map of Japan, the Headquarters for Earthquake Research Promotion, and the National Institute of Advanced Industrial Science and Technology. Comparing and analyzing the distribution of DSLs with corresponding active faults, we found following results. (1) DSLs induced by reverse fault earthquakes were distributed equally on a wide range of about 20 km from the active faults. On the other hand, more than 80% of DSLs induced by strike-slip fault earthquakes were concentrated within a narrow range of about 5 km to the active faults. (2) Most of the DSLs (24 out of 25 cases) induced by reverse fault earthquakes were distributed on the hanging wall side of the reverse faults. (3) As is shown in the cases of reverse faults, many DSLs in the cases of strike-slip faults earthquakes occurred in the hanging wall if the location of an epicenter is considered to be in the hanging wall.
As is known in the earthquake engineering field (e.g., Sato and Hirata, 2000, KAGAKU, vol. 70, No.1, 58-65, in Japanese), the damage caused by a strike-slip fault earthquake is more concentrated in a narrower range around the fault compared with the case by a reverse fault. A similar phenomenon was also confirmed for DSLs in this study. Many recent cases demonstrate that many DSLs occur in the hanging wall because the hanging wall suffers larger seismic motion than the foot wall by reverse fault earthquakes (e.g., Has Baator et al., 2010, JSECE annual meeting abstract, No. 57, 48-49, in Japanese). A similar result was also observed for the historical events. The discussion above suggests that, in addition to the distance to the nearest active fault of a potential landslide, we should take account of types of the active fault (reverse/strike-slip/normal) and whether the landslide is located in hanging or foot wall to assess the occurrence of earthquake-induced DSLs. The popular attenuation model (Si and Midorikawa, 1999, Journal of Struct. Construct. Eng., No. 523, 63-70, in Japanese) of peak ground velocity (PGV) that is commonly used for the building assessment is also required for similar considerations when used for the landslide assessment.

Keywords: deep-seated landslides, earthquake, reverse fault, strike-slip fault, hanging wall, foot wall

Simulation of the Aratozawa Landslide using Ring Shear Tests and LS-RAPID model

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The deep large-scale landslide near Aratozawa Dam of Miyagi Prefecture in Japan was occurred due to main shock of the Iwate-Miyagi inland earthquake on 14 June 2008. The earthquake magnitude reached 7.2 which results a huge mass movement close to the Aratozawa reservoir. Study on the Aratozawa landslide is necessary in order to understand and clarify the initiation mechanism and motion behavior particularly when the seismic loading plays as a main triggering factor. This paper shows the newest version of the undrained dynamic ring shear apparatus which then integrated with the LS-RAPID as a landslide simulation model. In further, results of this research could be a significant step forward for the landslide hazard assessment efforts to reduce human casualties and public infrastructure damage.
The laboratory experiment for the Aratozawa samples was carried out by means of ring shear apparatus ICL-2 version. This version is the newest apparatus that has been built so far by Sassa and other colleagues started in 2012 for practical use. Still, the main purposes of this apparatus for landslides are to observe the pore water pressure generation in undrained condition, shear strength reduction and failure motion behavior of samples within a large shear displacement. The development of this ring shear apparatus also emphasizing the change of normal stress platform from pillar-beam based, to the single central axis-based. Several parameters resulted from experiment by ring shear tests then occupied for the LS-RAPID geotechnical simulation. Landslide simulation model using LS-RAPID aims to observe the overall process of landslide phenomena started from the initiation process by pore pressure increase and seismic loading up to the moving process which involving the volume enlargement and traveling process of the landslide mass.
The critical pore pressure ratio was obtained from ring shear tests. In addition, the friction coefficient, shear displacement at the start of shear strength reduction and steady state shear resistance of the Aratozawa samples were also produced from the tests. We brought the results from ring shear tests as an input parameter in the LS-RAPID. The results of LS-RAPID so far could explain the initiation mechanism and motion of Aratozawa landslide. However, further detailed study is still needed, particularly for the factors from reservoir catchment and relation of reservoir and groundwater condition before and when the earthquake takes place.

Keywords: Aratozawa landslide, Ring shear tests, Shear strength reduction, LS-RAPID

Gravitational Slope Deformation in the Hiyoso District in the Central Kii Mountains

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In order to know the history of gravitational slope deformation, we investigated the deposits in ridge-top linear depressions formed by gravitational deformation in the Hiyoso district in the middle Kii Mountains. In the south area from this district, four huge deep-seated catastrophic landslides (Ui, Akatani-E, Akatani and Nagatono) occurred in 2011 by Typhoon Talas (Chigira, Tsou et al. 2013). Gravitational deformation is important for topographic precursors of deep-seated catastrophic landslides (Chigira, Tsou et al. 2013). This area is underlain by Jurassic-lower Miocene accretionary complexes. The strata belong to the Miyama Formation and the Hanazono Formation in the northern Zone of Shimanto Belt (Kurimoto, Kimura et al. 2015) .
We investigated the deposits at the two sites (HY1 and HY2). HY1 is correspond to the ridge-top linear depressions and HY2 is the almost flat plane formed under the down-facing scalps. We sampled the deposits by the penetration sampler made by Chigira and investigated the tephras and 14C ages of the humus soils. To identify the tephras in the deposits, the refractive index and the shape of the volcanic glass shards and heavy mineral assemblage were studied. The refractive index was measured by using thermal immersion method (RIMS).
As a result, we found three tephras, which could be correlated to regional key tephras. The newest tephra is the Kikai-Ah (K-Ah) and the middle one is Aira-Tn (AT). From the refractive index and the shape of the volcanic glass shards, we found that the oldest tephra near the base of the deposits might correspond to SI or Kj-P1 deposited 50 ka, suggesting that the gravitational deformation started at this age.
Chigira, M., et al. (2013). "Topographic precursors and geological structures of deep-seated catastrophic landslides caused by Typhoon Talas." Geomorphology 201: 479-493.
Kurimoto, C., et al. (2015). "Geology and radiolarian fossils of the Upper Cretaceous Hanazono Formation in the Koyasan area, northwestern part of Kii Peninsula, South west Japan." BULLETIN OF THE GEOLOGICAL SURVEY OF JAPAN 66(3-4): 41-79.

Keywords: gravitational deformation, linear depression, tephra

A test on infiltration induced sliding failure of a model slope

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This study built a 3m (width) x 2m (height) x 2m (thickness) model slope in Huisun Forest Experimental Station, Nantou, Taiwan. The purpose is to discuss the characteristics of the seismic signals and self-potential variation during failure of the model slope that induced by infiltration. Several accelerometers and self-potential electrodes were installed for monitoring. The water was placed on the top of the model slope to simulate infiltration. Cameras were installed to observe the failure process. The measured seismic signals were analyzed by empirical model decomposition and Hilbert transform and were compared with the self-potential data.

Keywords: landslide, seismic signal, self-potential, model slope, infiltration

Effect of ground freezing on landslide displacement during rainfall events

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In this study, we monitored landslide displacement, ground temperature and other related factors to understand the effect of ground freezing on the properties of landslide displacement in Hokkaido, Japan. Although intermittent landslide displacement was observed throughout the entire study period, a significant relationship between the increase in soil water content and landslide displacement was not established during rainfall on frozen ground events.

Keywords: ground temperature, soil water content, pore-water pressure

