Japanese-Croatian Project on Risk Identification and Land-Use Planning for Disaster Mitigation of Landslides and Floods in Croatia

BOOK OF ABSTRACTS

FACULTY OF CIVIL ENGINEERING, ARCHITECTURE AND GEODESY, UNIVERSITY OF SPLIT
4th Workshop
of the Japanese-Croatian Project on
‘Risk Identification and Land-Use Planning for Disaster Mitigation of Landslides and Floods in Croatia’

BOOK OF ABSTRACTS

12th-14th December, 2013.
Split, Croatia
Publisher: University of Split,
Faculty of Civil Engineering, Architecture and Geodesy
Matice hrvatske 15, 21000 Split, Croatia

Editors: Goran Vlastelica
Ivo Andrić
Daša Salvezani

Graphic Design: Ivo Andrić

Press: Faculty of Civil Engineering, Architecture and Geodesy

Responsibility for the accuracy of all statements in each paper rests solely with the author(s). Statements contained in the papers are not necessarily representative of, nor endorsed by Faculty of Civil Engineering, Architecture and Geodesy.

Permission is granted to copy portions of this publication for personal use and for the use of students provided credit is given to the authors, workshop and publication. Permission does not extend to other types of reproduction nor to copying for incorporation into commercial advertising nor for any other profit making purpose.
CONTENTS

FOREWORDS...........................................................................................................................................8

Overview of activity results of the Croatian-Japanese Project on “Risk Identification and Land-Use Planning for Disaster Mitigation of Landslides and Floods in Croatia” .......................................................... 9

Risk Identification and Land-Use Planning for Disaster Mitigation of Landslides and Floods in Croatia – Croatian Research Area .................................................................................................................. 10

WORKING GROUP 1: LANDSLIDES ........................................................................................................12

The Kostanjek Landslide in the City of Zagreb: Forecasting and Protective Monitoring ................. 13

Slope stability analyses of the Kostanjek Landslide for extreme rainfalls in the winter of 2013 ........ 15

Verification of mineralogical composition of Kostanjek landslide sediments using a visible and near-infrared (VIS-NIR) spectrometer ........................................................................................................ 17

Two years observation results of the Grohovo Landslide using integrated remote monitoring ......... 19

Shear strength properties of soil materials from the Grohovo Landslide .......................................... 20

Overview of Activities at Duće and Omiš Pilot Sites ............................................................................ 21

Dynamic Analysis of rock slope in Duće area ....................................................................................... 23

Comparison of Terrestrial Laser Scanners for slope stability monitoring ....................................... 24

Application of Terrestrial Laser Scanning and Sensor Networks for Landslide Monitoring .......... 25

Characteristics of sliding displacement of Kostanjek landslide in Croatia ....................................... 27

Slope stability analysis and mitigation measures in the area of the Sibiu-Orastie motorway viaduct .... 28

Urgent rock fall stabilization by planned demolition ............................................................................. 29

Engineering geology process induced by salt exploitation in Tuzla town ........................................... 31

Example landslide remediation on a railroad track near Banja Luka .................................................. 32

WORKING GROUP 2: FLASH FLOODS AND DEBRIS FLOWS .................................................................33

Water related risks .................................................................................................................................. 34

Morphometry of Red Lake using LiDAR and SoNAR technology ......................................................... 35

Influence of extreme climate conditions on runoff .............................................................................. 36
Groundwater behaviour in the Kostanjek landslide, western part of Zagreb, Croatia: geochemical constraints from water and rock samples........................................................................................................37

Assessment of Rainfall as a trigger on Grohovo Landslide..........................................................................................38

Disaster Mitigation of Floods and Debris Flow at Rijeka Region through Croatian-Japanese Collaboration . 40

Relationship between atmospheric conditions and groundwater level on Grohovo landslide.......................... 43

Applicability analysis of erosion assessment methods based on defined criteria and available data.......... 44

Application of ‘Structure-from-Motion’ photogrammetry for erosion processes monitoring, Mošćenička Draga example........................................................................................................ 46

Performance analysis of X-band radar rainfall measurements in the Kvarner region............................................... 48

Application of SPH method to create numerical models of Debris flow propagation................................................. 49

Physical modelling of debris flow movement - laboratory research........................................................................... 50

Analysis of the rainfall impact on variation of the underground water level on the Slani potok catchment area .................................................................................................................................. 52

Explicit vs. Implicit Time Integration of Saint-Venant Equations for Flood Wave Propagation............................ 54

WORKING GROUP 3: HAZARD MAPPING.................................................................................................................. 55

Awareness of Flood Risk in different generations in Zagreb........................................................................................ 56

Hazard Mapping for WG4 Case Study .................................................................................................................... 57

Overview of Input Data for the Landslide Hazard Analysis in the Dubračina River Basin........................................... 58

Landslides Triggered in the City of Zagreb in the Winter of 2013.................................................................................. 60

A deep structural borehole on Medvednica hilly zone – review of new data and possible reinterpretation of existing geological model ........................................................................................................ 62

Stereoscopic analysis of landsides on the southern slopes of the Mt. Medvednica and landslide features assessment – examples and field check.................................................................................. 64

Geohazard a Part of Innovative Inspire Compliant Cloud Based Infrastructure - InGeoCloudS ....................... 65

Project MASPREM an early warning system for landslide ......................................................................................... 66

Landslides, distribution and their consequences in the Tirana area........................................................................ 68

The Influence of Anthropogenic Interventions on the Risk and the Degree of Damage to the Land and Buildings in Bosnia and Herzegovina ........................................................................... 69
Organizing institutions:

- University of Split, Faculty of Civil Engineering, Architecture and Geodesy - executive organiser
- University of Rijeka, Faculty of Civil Engineering
- University of Zagreb, Faculty of Mining, Geology and Petroleum Engineering
- University of Zagreb, Faculty of Agriculture
- Croatian Geological Survey
- Kyoto University, Disaster Prevention Research Institute (DPRI)
- Niigata University
- City of Omiš

Workshop is supported by:

- Ministry of Science, Education and Sports, Republic of Croatia (MZOS)
- Japan International Cooperation Agency (JICA)
- Japan Science and Technology Agency (JST)
- University of Split
- Croatian Geological Survey
- University of Split, Faculty of Civil Engineering, Architecture and Geodesy

Organizing Committee:

Hideaki Marui - WORKSHOP CHAIR
Research Institute for Natural Hazards and Disaster Recovery, Niigata University

Nevenka Ožanić - WORKSHOP CHAIR
University of Rijeka, Faculty of Civil Engineering

Predrag Miščević
University of Split, Faculty of Civil Engineering, Architecture and Geodesy

Snježana Knezić
University of Split, Faculty of Civil Engineering, Architecture and Geodesy

Hideaki Komiyama
Japan International Cooperation Agency (JICA)

Roko Andričević
University of Split, Vice-rector for Science and International Relations

Snježana Mihalić Arbanas
University of Zagreb, Faculty of Mining, Geology and Petroleum Engineering

Željko Arbanas
University of Zagreb, Faculty of Mining, Geology and Petroleum Engineering

Ivan Vrkljan
Faculty of Civil Engineering, University of Rijeka

Ivica Kisić
Faculty of Agriculture, University of Zagreb

Željko Miklin
Croatian Geological Survey
4th Workshop of the Japanese-Croatian Project on ‘Risk Identification and Land-Use Planning for Disaster Mitigation of Landslides and Floods in Croatia’
Split (Croatia), 12-14 December 2013

Technical Committee:

Predrag Miščević
University of Split, Faculty of Civil Engineering, Architecture and Geodesy
Snježana Knezić
University of Split, Faculty of Civil Engineering, Architecture and Geodesy
Petra Šimundić
University of Split, Science Manager
Ivo Andrić
University of Split, Faculty of Civil Engineering, Architecture and Geodesy
Goran Vlastelica
University of Split, Faculty of Civil Engineering, Architecture and Geodesy
Daša Salvezani
University of Split, Faculty of Civil Engineering, Architecture and Geodesy
Nataša Štambuk Cvitanović
University of Split, Faculty of Civil Engineering, Architecture and Geodesy
Zora Lelas Ković
City of Omiš, Assistant to the City Government

Workshop Scientific Committee:

Željko Arbanas
University of Rijeka, Faculty of Civil Engineering
Barbara Karleuša
University of Rijeka, Faculty of Civil Engineering
Predrag Miščević
University of Split, Faculty of Civil Engineering, Architecture and Geodesy
Snježana Knezić
University of Split, Faculty of Civil Engineering, Architecture and Geodesy
Ognjen Bonacci
University of Split, Faculty of Civil Engineering, Architecture and Geodesy
Hideaki Marui
Research Institute for Natural Hazards and Disaster Recovery, Niigata University
Snježana Mihalić Arbanas
University of Zagreb, Faculty of Mining, Geology and Petroleum Engineering
Nevenka Ožanić
University of Rijeka, Faculty of Civil Engineering
Kyoji Sassa
International Consortium on Landslides, Kyoto University
Fawu Wang
Research Center on Natural Disaster Reduction, Shimane University
Yosuke Yamashiki
Disaster Prevention Research Institute, Kyoto University
Hiroshi Fukuoka
Disaster Prevention Research Institute, Kyoto University
Gen Furuya
Toyama Prefectural University, Faculty of Engineering
FOREWORDS
Overview of activity results of the Croatian-Japanese Project on “Risk Identification and Land-Use Planning for Disaster Mitigation of Landslides and Floods in Croatia”

Hideaki Marui
Research Institute for Natural Hazards and Disaster Recovery, Niigata University, Japan
maruihi@cc.niigata-u.ac.jp

At the beginning of the workshop an overview of essential research results of the Croatian-Japanese Joint Project will be provided, as it will be terminated soon at the end of March 2014.

The Croatian-Japanese joint research team have been making every endeavour to develop a mitigation methodology of disasters caused by landslides and floods through the basic scientific study of their mechanism and through the risk identification method which is suitable for Croatian societal and natural conditions. The objective of the joint research project is to develop an integrated landslide/flood hazard mapping technology and land-use guidelines formulation methodology for nation-wide application in Croatia. This objective was almost attained through the following three research steps: (1) Methodologies for landslide risk assessment, prediction of affecting areas and early warning was developed adapting to hydrological and geological conditions in Croatia. (2) Flash-flood/debris-flow simulation models and early warning systems was developed adapting to hydrological and geological conditions in Croatia. (3) Basic methodology of integrated landslide/flood hazard mapping and land-use guidelines formulation for landslide/flood risk mitigation were developed. Almost all individual research items in the three steps mentioned above were already accomplished. The following items are essential outputs attained through the Joint Project: (1) Individual landslide topographies in each target areas were identified based on aerial photo interpretation. Further, the danger degree of the each individual landslide topography was evaluated by the Analytical Hierarchy Process (AHP) method. (2) Comprehensive monitoring system on landslide movements was installed in Grohovo landslide area near Rijeka and also in Kostanjek landslide area in Zagreb City. (3) Prediction of travel distance for selected representative landslides was carried out using shear strength parameters measured by the newly developed portable ring shear apparatus. (4) Simulation methods on flash-floods and debris flows were developed. (5) Flood discharge monitoring systems were installed in selected target areas. (6) Flood risk was analysed by simulation using the proper hydrological model. (7) Prototype hazard maps on landslide disasters were developed for selected target areas. They should be integrated with another hazard maps on flash-floods. In addition to the previous research items which were listed already in the original research plan, it is also necessary to mention about the unforeseen critical situation in Kostanjek landslide in April this year. Unusual quick movement of sliding soil mass was measured by the monitoring system installed in the Kostanjek landslide area since early stage of March. Therefore, Japanese research team has dispatched several experts in early stage of April in order to arrange emergency management operation. They have made field investigations to detect actual displacement of sliding soil mass and given suggestions to representatives of OEM of Zagreb City. Furthermore, in addition to the research items capacity buildings and technology transfer are also important aspects of the Joint Project. Croatian young researchers were invited to several training courses prepared in Japan for capacity building. Already 1st, 2nd and 3rd Regional Workshops were organized in Croatia for technology transfer to the neighbouring countries. Now at the last stage of the Joint Project, the research teams are going to formulate the final version of integrated landslide/flood hazard maps and also land-use guidelines for target areas.

Prof. Hideaki Marui
Project Leader
Risk Identification and Land-Use Planning for Disaster Mitigation of Landslides and Floods in Croatia – Croatian Research Area

Nevenka Ožanić
Faculty of Civil Engineering, University of Rijeka, Croatia
nevenka.ozanic@gradri.hr

Project „Risk Identification and Land-Use Planning for Disaster Mitigation of Landslides and Floods in Croatia“ was submitted on the international call of the Government of Japan for scientific research projects in 2008 as one of 10 projects in program Science and Technology Research Partnership for Sustainable Development financed by Japan Agency for Science and Technology-JST and Japan International Cooperation Agency-JICA. Japanese partner institutions in the Project are Niigata University (The Research Centre for Natural Hazards and Disaster Recovery), Kyoto University (Disaster Prevention Research Institute, DPRI) and International Consortium on Landslides (ICL). Croatian partner institutions in the Project are University of Rijeka (Faculty of Civil Engineering), University of Zagreb (Faculty of Mining, Geology and Petroleum Engineering and Faculty of Agriculture) and University of Split (Faculty of Civil Engineering, Architecture and Geodesy) and Croatian Geological Survey. Predicted duration of the project is five years.

The main activities of the research groups involved in the Croatian-Japanese research Project include investigations of recent landslides using landslide monitoring, the establishment and development of early warning systems for landslides, flash flood and debris-flow simulation models, development of early warning systems adapted to hydrological and geological conditions in Croatia and the definition of hazard zones using a methodology for assessing susceptibility and hazards based on local geological and landslide conditions. The final objective is the development of risk mitigation measures that can be instituted through urban planning. In the framework of the Working Group on Landslides (WG1) a systematic monitoring in real time, laboratory analysis of soil samples and numerical analysis of the behaviour of landslides in static and dynamic conditions on the landslide Grohovo and landslides Kostanjek in the City of Zagreb are carried out. Working Group for Flash-Floods and Debris Flow (WG2) conduct observations of meteorological and hydrological parameters in the analysed catchment areas in real time; numerical and hydrological analysis of the measured parameters; and the development of simulation models of floods, mud flows and flow, making an early warning system on these phenomena. Selected research areas are in the vicinity of Rijeka and Split.

Activities of Hazard Mapping and Land-use Guidelines Working Group (WG3) included the development of inventory of landslides using remote sensing techniques and methods of analyses and hazard zoning. Japan-Croatia workshop - Risk identification and land-use planning for disaster mitigation of landslides and floods in Croatia was held at the University of Niigata in February 2010. Regional cooperation has been initiated by organizing the 1st Project Workshop entitled ‘International Experience’, which was held in Dubrovnik (Croatia) in November 2010. The workshop addressed a range of topics in the fields of investigation of the Japanese and Croatian Project members and regional guest experts from eight universities, two geological surveys and four institutes. Guest scientists from Bosnia and Herzegovina, Bulgaria, Macedonia, Serbia and Slovenia participated. General concept of the organization of regional scientific network was discussed at the 2nd Project Workshop in Rijeka (Croatia) in December 2011 entitled „Monitoring and analyses for disaster mitigation of landslides, debris flow and floods“. This workshop was intended for Japanese and Croatian project participants and also for scientist and experts from neighbouring countries of Croatia who are involved in research of natural phenomena (landslides and flash floods) aimed at mitigation of related hazard and risk. Abstracts and papers were published in Book of abstracts and in Book of proceedings.

Regional cooperation among Croatia, Slovenia, Serbia and Albania was formalized in the frame of regional ICL Adriatic-Balkan Network in January in Kyoto 2012. 3rd Workshop of the Japanese-Croatian Project on ‘Risk Identification and Land-Use Planning for Disaster Mitigation of Landslides and Floods in Croatia’ and 1st Regional Symposium on Landslides in the Adriatic-Balkan Region entitled ‘Landslide and flood hazard assessment’ was organized in Zagreb from 7-9 March 2013. This Project Workshop and Regional Symposium was intended for Japanese and Croatian Project members, as well as for scientist, experts and professionals from Croatia and neighbouring countries who are involved in research of natural phenomena (landslides and flash floods) aimed at mitigation of related hazard and risk. This was an outstanding opportunity for scientist in the fields of geological, geotechnical and hydrotechnical engineering and risk management to share and increase knowledge through presentations of their work and research. Last 4th Workshop of the Croatian - Japanese Project on ‘Risk Identification and Land-Use Planning for Disaster Mitigation of Landslides and Floods in Croatia’ was organized from 12-14 December in Split, Croatia.
The workshops will contribute to the establishment and development of regional cooperation, which is important for the sustainability of project results even after the project ends in March 2014.

Prof.dr.sc. Nevenka Ožanić
Project Manager – Croatian side
WORKING GROUP 1: LANDSLIDES
The Kostanjek Landslide in the City of Zagreb: Forecasting and Protective Monitoring

Martin Krkač, Snježana Mihalić Arbanas, Sanja Bernat
Faculty of Mining, Geology and Petroleum Engineering, University of Zagreb, Croatia

The monitoring system at the Kostanjek landslide consists of various sensors for the measurement of: (1) external triggers (rain gauge and accelerometers); (2) hydrological properties (pore pressure gauges and water level sensors in boreholes and domestic wells, water level sensors at outflow weirs); (3) displacement/deformation/activity (GNSS sensors, extensometers, borehole extensometers and inclinometers. Rainfall has been monitored with a 0.5 mm tipping-bucket rain gauge installed at the central part of the Kostanjek landslide since September 2011. According to historical data, the average rainfall for the period of 1962-2012 in the Zagreb city area is 874.4 mm (Krkač et al. 2012). Total rainfall in 2012, measured by rain gauge, was 784.5 mm, while rainfall during the first nine months of 2013 was 668 mm. In the period from December 2012 to March 2013, the total rainfall quantity of 455.2 mm caused a reactivation of the Kostanjek landslide.

An inclinometer tube was installed in March 2012 in a 100 meter deep borehole placed in the central part of the landslide. The inclinometric profile, obtained on the basis of three measurements, indicates that the failure occurs in a thin basal shear zone at the depth of 62.5 meters. Deformation above 62.5 meters can be considered negligible related to landslide mechanisms. Deformation also occurred at the depth of 15 to 30 meters, but it is most probably a consequence of borehole casing deformations due to improper inclinometer tube installation.

Seven long- and two short-span wire extensometers, which provide continuous data on relative displacement with sub-millimetre precision, are installed at six locations. During the winter period of 2012/2013, three of the seven extensometers, installed at that time, showed significant displacement, respectively the long-span extensometer crossing the main scarp, the short-span extensometer crossing the fracture in east part of the landslide and the short-span extensometer crossing the sliding surface in the abandoned tunnel. All three extensometers displayed extension, but the amount of measured displacement varies from 40 mm on the fracture at the east side of the landslide body to 72.5 mm on the main scarp and 97 mm in the central part where the sliding surface intersects the tunnel.

The GNSS monitoring system, for continuous surface displacement measurement, consists of 15 GNSS reference stations. The sixteenth GNSS reference station is considered to be a stable GNSS and it is located approximately 7 kilometers south of the landslide. During the monitoring period, almost all sensors measured horizontal displacement in a range from 4 to 20 cm. Fig. 1 displays the evolution of 2D surface displacement registered by four GNSS sensors, within the period of major displacement from December 2012 to May 2013. The maximum rates of displacement, with velocities of 2 to 4 mm/day, occurred during the first week of April. On Fig. 1 it is evident that the amount of displacement in the central part of the landslide and in the foot part is approximately two to four times higher than the displacement near the landslide borders.

![Fig. 1 Cumulative horizontal displacements versus time for GNSS 2 and 13 (near the landslide boundary), GNSS 8 (central part of the landslide) and GNSS 9 (landslide foot).](image-url)
According to DiBiagio and Kjekstad (2007), an efficient EWS should comprise the following activities: (1) monitoring, including data acquisition, transmission and maintenance of the instruments; (2) analysis and forecasting, which can be done by using thresholds, expert judgment, forecasting methods and so on; (3) warning; (4) response, i.e. actions taken in the case of a dangerous event. The Kostanjek landslide monitoring system is almost completely finished with the installation of monitoring equipment. The next stage of system setup is the establishment of data transmission for almost of sensors. So far, the data transmission is set up for 15 GNSS sensors and Osasi Technos Inc. sensors (3 pore pressure gauges, 4 vertical extensometers and a rain gauge) located at the main monitoring station in the central part of the landslide. Raw data from the GNSS in real-time and data from Osasi devices (every hour) are delivered over communication lines (using routers) to an application/data server at the University of Zagreb. GNSS data is processed by Trimble 4D Control software and Osasi sensor data is processed by Onset Observer software. In order to integrate data from all the sensors in the GIS (Geographic Information System), customized GIS application is currently under development (Baučić et al. 2013).

The forecasting of landslide failure in the periods of landslide reactivation, at first will be based on the Fukuzono (1985) method of inverse velocities and the Saito (1969) method of tertiary creep using data from the extensometer and GNSS sensors. After a longer period of monitoring, data analysis should enable an estimation of the relationship between landslide causal factors and landslide displacement rates. This relationship will be used for the establishment of the threshold values for the early warning system. Final activities related to warning and response should be made in collaboration with the following Zagreb City offices: (1) Emergency Management Office of the Zagreb City which deals with protecting activities against natural hazards; and (2) Zagreb City Office for Physical Planning, Construction of the City, Utility Services and Transport which deals with landslides remediation.

References


Address for correspondence:

Author’s Name: Martin Krkač
Institution: Faculty of Mining, Geology and Petroleum Engineering, University of Zagreb
Address: Pierottijeva 6, 10000 Zagreb, Croatia
Phone: +385 1 5535 896
E-mail: mkrkac@rgn.hr
Slope stability analyses of the Kostanjek Landslide for extreme rainfalls in the winter of 2013

Karolina Gradiški, Martin Krkač, Snježana Mihalić Arbanas, Sanja Bernat
Faculty of Mining, Geology and Petroleum Engineering, University of Zagreb, Croatia

The Kostanjek landslide in the City of Zagreb is one of the pilot areas within the scientific Croatian-Japanese SATREPS FY2008 project ‘Risk Identification and Land-Use Planning for Disaster Mitigation of Landslides and Floods in Croatia’. It is located in the western part of the City of Zagreb, in residential area at the base of the southwestern slope of the Medvednica Mt. The Kostanjek landslide was activated in 1963 by excavation in two open pit mines. Massive blasting and excavation in the foot of the slope caused slope movements within an area of 1.2 square kilometres. A landslide model was proposed by Ortolan (1996) on the basis of geotechnical investigations from 1984 to 1989. According to this model there are three sliding surfaces at different depths. The depth of the deepest sliding surface is about 90 m; the depth of the intermediate sliding surface is 65 m, while the superficial sliding surface is about 50 m deep. In the frame of the Croatian-Japanese project on the Kostanjek landslide monitoring system was established. The system consists of sensors for measuring displacement, hydrological properties and external triggers (Mihalić et al., 2013). Based on the monitoring data from GNNS sensors, extensometers, borehole extensometers and inclinometers it was concluded that Kostanjek landslide is deep-seated large translational landslide with one sliding surface.

This paper presents results of slope stability analyses performed using the LS-RAPID software (Integrated Landslide Simulation Model). Unlike the Ortolan’s model, where the sliding surface reaches maximum depth of the 90 m in the southeastern part of the landslide body, in these analyses the sliding surface was created in the form of ellipsoidal sliding surface with maximum depth at the central part of the landslide body. According to the previous analyses (Gradiški et al. 2013) it was concluded that it is more likely that sliding surface is not so deep in the southeastern part of the landslide body. For reliable interpretation of the sliding surface depths, additional subsurface investigations are necessary. Parameters used for these analyses were determined from drained test of samples in ring shear apparatus. The samples were taken from the core on the assumed position of the sliding surface at the depth of around 65 m. The testing of the samples was carried out by Maja Oštrić in the frame of the Croatian-Japanese SATREPS FY2008 project.

The extreme rainfalls in the winter of 2013 caused a reactivation of the Kostanjek landslide. Monitoring sensors at the Kostanjek landslide recorded greater displacements in the central part of the landslide than the displacement at the landslide borders (Krkač et al., 2013). The meteorological data from the hilly area of the City of Zagreb shows the following extremes (Bernat et al. 2013): cumulative monthly precipitation in January, February and March in 2013 was two to three times higher than the average monthly values for the period from 1862 to 2012; and cumulative precipitation for a 3-month period in 2013 has the highest value in the last 150 years. Taking into account the extreme rainfalls in the winter of 2013 it was assumed that the sliding surface was fully saturated and the pore pressure ratio was set as a fluctuating value and it was increased from 0.3 to 0.8. In these analyses only the rainfall was taken as triggering factor for the landslide occurrence.

According to the results of the analyses, the more unstable part of the landslide is the central part of the landslide body, i.e. the slopes of the abandoned old open marl pit. In the analyses the movements started at the central part of the landslide body after that the failure area will expand around the initial failure zone. At the end of simulation the area of the whole landslide mass corresponds to the landslide contour from Ortolan’s model (from 1996) and to the new landslide deformations (cracks, bulging, subsidance) identified in the field after March 2013 (Fig.1).

These analyses were performed for the assumed pore pressure on the sliding surface. For more precisely analyses it is necessary to define more precisely: sliding surface with more correct positions along particular landslide cross sections; water table surface derived on the basis of measured water levels; and performed undrained ring shear test to determined more appropriate soil parameters.
Fig. 1 Slope stability analyses of the Kostanjek Landslide for $r_u=0.3$, $r_s=0.3$, $r_a=0.3$

References


Ortolan Ž (1996) Development of 3D engineering geological model of deep landslide with multiple sliding surfaces (Example of the Kostanjek Landslide) PhD thesis. Faculty of Mining, Geology and Petroleum Engineering, University of Zagreb, Zagreb (In Croatian)

Address for correspondence:
Author’s Name: Karolina Gradiški
Institution: Faculty of Mining, Geology and Petroleum Engineering, University of Zagreb
Address: Pierottijeva 6, 10000 Zagreb, Croatia
Phone: +385 1 5535 898
E-mail: karolina.gradiski@rgn.hr
Verification of mineralogical composition of Kostanjek landslide sediments using a visible and near-infrared (VIS-NIR) spectrometer

Jasmina Martinčević Lazar(1), Goran Vlastelica(2), Sanja Bernat(3), Željko Miklin(1), Laszlo Podolszki(1)

(1) Croatian Geological Survey, Zagreb, Croatia
(2) University of Split, Faculty of Civil Engineering, Architecture and Geodesy, Split, Croatia
(3) University of Zagreb, Faculty of Mining, Geology and Petroleum Engineering, Croatia

One of key point in the investigation and interpretation of sliding and swelling phenomena in nature materials is the role of mineralogical composition on physical and mechanical properties, especially regarding clay minerals. Therefore detailed investigations of the mineralogical composition of Kostanjek landslide sediments were conducted.

The Kostanjek landslide is the largest landslide in Medvednica Mt. hilly zone placed in the residential area of the City of Zagreb. It was activated in 1963 due to massive blasting in the Bizek Quarry and excavation in a marl quarry at the foot of the hill. Unlike to all other landslides in Medvednica Mt. hilly zone which are mostly small shallow landslides, the Kostanjek landslide is an atypical, deep-seated large translational landslide with multiple (re)activations of landslide bodies (Ortolan, 1996; Mihalić Arbanas et al., 2013). Except sliding, in the area of the Kostanjek landslide there are evidences of subsidence and bulging of ground surface that might be associated with the processes of swelling. This phenomenon is usually noticed after the periods of heavy rain or dry summer. Kostanjek landslide is also one of the pilot areas in the frame of the Croatian – Japanese SATREPS FY2008 joint research project on “Risk Identification and Land – Use Planning for Disaster Mitigation of Landslides and Floods in Croatia” (Krkač et al., 2011).

According to historical data, the mineralogical analyses of Kostanjek landslide sediments were performed by Balen (1975) and Slovenec (1989) but only on the samples from the marl quarry. In the frame of scientific activities of the Croatian – Japanese project, one 100 m deep borehole was drilled in the middle part of the Kostanjek landslide in 2012. The core inspection revealed four lithological units as follows: (1) engineering soil of Quaternary age (0 – 10 m), (2) Upper Pannonian massive marls (10 – 45 m), (3) Lower Pannonian marls intercalated with limestone (45 – 60 m) and (4) Sarmatian thin laminated marls (60 – 100 m). For the purpose of mineralogical analyses a total of 17 samples were collected, several from each unit. The samples was analysed by X-ray powder diffraction method on random and oriented mounts after certain treatments. Based on interpretation of X-ray diffraction patterns a quantitative mineral composition (w %) of whole rock was obtained and a semi quantitative content of clay minerals were also determined, among which the most abundant were smectite clays (Martinčević et al., 2012).

It is well known that clay minerals have a main role in the processes of swelling, especially those from smectite group (Grim, 1968). To verify the results obtained by x – ray diffraction the method of visible and near – infrared (VIS-NIR) spectroscopy was used. The operating principle of the method is based on sending light onto the sample and then measuring the light which is reflected back from the sample. Frequencies which are absorbed appear as a reduced signal of reflected radiation. The measured wavelength region ranges from 380 – 2500 nm which mean that covers a visible (400-700 nm) and near-infrared (700-2500 nm) regions. The spectral patterns include overtones and combination bands that occur from chemical bonds within soil minerals (Visscara Rossel et al., 2009; Stenberg et al., 2010).

Analysis were performed in laboratory, on the above mentioned core samples using a portable Terraspec Explorer spectrometer. The interpretation of results was based only on qualitative description of spectral patterns (Fig. 1). A special attention was given to the samples from the first two units (0-20 m) which are placed in unsaturated zone. Before the scanning, samples were dried on the air and grinded to the fraction less than 2 mm. As a result of the samples drying the effect of natural moisture should be negligible. The most common minerals in the clay fraction are smectite, kaolinite and muscovite. Smectite has two very strong water bends near 1400 and 1900 nm from molecular water and another at 2200 nm. Kaolinite is an aluminium silicate with strong reduced signal near 1400 nm due to OH stretch, and smectite clays (Martinčević et al., 2012).

Samples from first, second and fourth unit have in spectral pattern the large reduced signal near 1400 and 1900 which were associated with molecular water in clay minerals. In spectral pattern of samples from third unit this signal is smaller than in other samples. Based on these results, it can be concluded that, for some reasons, the clay minerals incorporated less water molecules in their crystal lattice. The reduced signals near 2200 nm are constant through the spectral patterns of all samples. According to the other reduced signals a presence of iron oxides and oxyhydroxides (near 900 nm) and calcite component (2330 nm) was identified. As expected, the identification of soil mineral composition by VIS-NIR spectroscopy was in general with good agreement to the results obtained by X-ray diffraction.
Fig. 1 Spectral patterns of samples from the massive marls unit with large reduced signals near the 1400, 1900 nm (molecular water), 2200 nm (clay minerals) and 2340 nm (calcite)

Acknowledgement

First, we would like to thank you to Professor Snježana Mihalić Arbanas and her assistant Martin Krkač from Faculty of Mining, Geology and Petroleum (Zagreb) for accurately collected samples. Also we would like to establish that this investigation was performed in the frame of Croatian-Japanese SATREPS FY8 joint research project on “Risk Identification and Land – Use Planning for Disaster Mitigation of Landslides and Floods in Croatia”.

References

Balen I., Tišljar J., & Majer V. (1975); Petrografiske karakteristike lapora iz okolice Podsuseda na jugozapadnim obroncima Medvednice (Petrographic characteristics of marl from Podsused area on the southwestern slopes of Medvednica Mt.); Geološki vjesnik, Institu za geološka istraživanja u Zagrebu, Zagreb; 28, pp. 167-172.


Krkač M., Rubinič J., Mihalić S. (2011); Landslide Kostanjek – Analyses of groundwater discharge as a basis for the new hydrological monitoring; Proceedings of 2nd Project Workshop on Monitoring and analyses for disaster mitigation of landslides, debris flow and floods; University of Rijeka, Faculty of Civil Engineering, Croatia, pp. 17-20.


Ortolan Ž. (1996); Development of 3D engineering geological model of deep landslide with multiple sliding surfaces (Example of the Kostanjek Landslide); PhD Thesis; Faculty of Mining, Geology and Petroleum Engineering, University of Zagreb, Zagreb, p.203 (In Croatian).

Slovenec D. (1989); Mineraloške karakteristike sedimenata s lokacije T.C. “SLOBODA” u Podsusedu (Mineralogical characteristics of sediments from “SLOBODA” quarry in Podsused); Department for mineralogy, petrology and economic geology; Faculty of Mining, Geology and Petroleum Engineering, University of Zagreb, Zagreb, p.56


Address for correspondence:

Author’s Name: Jasmina Martinčević Lazar
Institution: Croatian Geological Survey - CGS
Address: Milana Sachsa 2, 10000 Zagreb, Croatia
Phone: +38516160727
E-mail: jmartincevic@hgi-cgs.hr
Two years observation results of the Grohovo Landslide using integrated remote monitoring

Josip Peranić(1), Sanja Dugonjić Jovančević(1), Vedran Jagodnik(1), Martina Vivoda(1), Osamu Nagai(2), Kyoji Sassa(2), Željko Arbanas(1)

(1) Faculty of Civil Engineering, University of Rijeka, Rijeka, Croatia
(2) International Consortium on Landslides, Kyoto, Japan

The advanced comprehensive monitoring system was designed and applied to the Grohovo Landslide in the Rječina River Valley, Croatia, in the frame of the Croatian Japanese bilateral scientific project on ‘Risk Identification and Land-Use Planning for Disaster Mitigation of Landslides and Floods in Croatia’. The monitoring equipment was selected based on landslide characteristics, equipment possibilities related to field conditions, so as scientific requirements. The focus of the monitoring system establishment was on effective combination of sensors (equipment fusion) Necessary improvements of existing monitoring system have been analyzed and presented on the basis of 1.5 year period of measurement.

The use of multiple sensors at the same measuring point should guarantee the possibility to check redundancy and correlation of measurements. Equipment fusion is also useful in prevention of losing data if one instrument fails. Usage of geodetical and geotechnical equipment fusion in combination with hydrological monitoring equipment, enables reconstruction of the relationships between rainfalls, groundwater levels and landslide response. The results of monitoring system should provide basis for development and validation of numerical models and adequate early warning system inside the landslide hazard management framework. In order to provide establishment of the reliable early warning system alarm thresholds should be based on existing cognition of the Grohovo landslide behavior, which depends greatly on the reliability of the gathered monitoring data.

In this paper, an overview of the two years observations results of the Grohovo Landslide using an integrated remote monitoring system as well as brief overview of the latest upgrades in the installed system will be presented. Since the monitoring system on the Grohovo landslide integrates two different types of monitoring, data will be presented accordingly. The latest data from the overall geotechnical monitoring system, was collected in the early September 2013, during the system upgrade and maintenance works. Regarding the geotechnical part of the monitoring system, data presented in this paper includes records from long span extensometers, short span extensometers, vertical extensometers and inclinometers. Second part of the data presented in this paper refers to geodetic monitoring. This part of the Grohovo Landslide monitoring system includes geodetic surveys of 25 benchmarks (prisms) observed by robotic total station and measurements from 9 GPS receivers (rovers) connected in local GPS network. Analyse of equipment in fusion behavior will be presented through the analyses of results of different monitoring sensors installed at the same points, which in case of this paper refers to poles containing both geodetic prisms and GPS rovers. Data reviews will include standard components used to describe chain of events recorded by installed sensor.

Address for correspondence:
Author’s Name: Željko Arbanas
Institution: Faculty of Civil Engineering, University of Rijeka
Address: Radmile Matejčić, 3, 51000 Rijeka, Croatia
Phone: +385 1 51 265 902
E-mail: zeljko.arbanas@gradri.uniri.hr
The shear strength characteristics of soil materials have the main role in determination of slope behaviour. Examination of soil strength characteristics is in most situations based on laboratory test conducted on soil samples taken from slip surface zone using different shearing devices. In this paper we will present an overview of laboratory shear strength test results carried out on samples from the Grohovo Landslide soil and their impact on slope behaviour. The Grohovo landslide is situated in the central part of the Rječina River Valley near the city of Rijeka. A lot of instabilities on the slopes of the Rječina River Valley were recorded during the 19th and 20th century and the last landslide was reactivated on the north eastern slope near the Grohovo Village in December 1996. The Grohovo Landslide was chosen as pilot site of the Croatian–Japanese Bilateral Project “Risk identification and Land-Use Planning for Disaster Mitigation of Landslides and Floods in Croatia”, and a comprehensive integrated real-time monitoring system, consisted of geodetic and geotechnical equipment was installed in 2011. Measured displacements inside the slope profile clearly indicated position of slip surface that is identified at the contact of slope superficial deposits and flysch bedrock. The flysch bedrock mainly consists of siltstones while slope superficial deposits are mostly a mixture of clayey silts and limestone’s fragments and blocks. Soil testing was conducted on samples taken from boreholes in the portable ring shear apparatus ICL-1. This apparatus was designed for testing the residual shear resistance mobilized along the sliding surface at large shear displacements under static and/or dynamic local conditions. Undrained speed control tests were conducted under constant shear speed until steady state condition was obtained. From this test basic material properties, mobilized and apparent friction angle and mobilized cohesion, are gained. Obtained test results are in accordance with results obtained in previous laboratory tests, and conducted slope stability back analyses. The previous laboratory tests, conducted in direct shear apparatus, didn’t give reliable undrained strength parameters because it was impossible to prevent localized drainage away from the shear plane. It wasn’t possible to measure pore pressures in the direct shear box; and consequently, it wasn’t possible to determine effective stresses. Determination of effective stresses during shearing in ring shear apparatus is enabled by measuring pore water pressure using pore transducers installed near the shear plane. Previous 2D slope stability analyses were based on direct shear laboratory results and resulted safety factors pointed on too high shear strength parameters. Conducted slope stability back analysis resulted by lower effective shear strength parameters. The forms, shapes and geometries of landslide bodies in this complex landslide consisted of 13 different landslide bodies, point on using of 3D stability analysis, where the resistance on landslide’s flanks have significant impact on resulting factor of safety. Comparison of shear strength parameters obtained from direct shear and ring shear tests, so as from 2D and 3D slope stability back analyses point on average mobilized shear strength parameters of soil material on slip surface during occurrence of the Grohovo Landslide.

Address for correspondence:
Author’s Name: Martina Vivoda
Institution: Faculty of Civil Engineering, University of Rijeka
Address: Radmile Matejčić,3, 51000 Rijeka, Croatia
Phone: +385 1 51 265 988
E-mail: martina.vivoda@gradri.uniri.hr
Overview of Activities at Duće and Omiš Pilot Sites

Goran Vlastelica(1), Predrag Miščević(1), Hiroshi Fukuoka(2), Gen Furuya(3), Branko Kordić(4)

(1) University of Split, Faculty of Civil Engineering, Architecture and Geodesy, Split, Croatia
(2) Kyoto University, Disaster Prevention Research Institute, Kyoto, Japan
(3) Toyama Prefectural University, Faculty of Engineering, Toyama, Japan
(4) University of Zagreb, Faculty of Geodesy, Zagreb, Croatia

Dalmatia region in Croatia has dozens of registered active rockfall zones. Virtually whole area along main coastal road from city of Split to town of Omiš is a potential danger zone for inhabitants and community infrastructure. Almost every year, in periods after heavy rain and/or considerable low air temperature, many sudden rockfalls in this area are recorded. Stabilizing and managing the entire area without localising potential threats would require considerable funding, which private owners and local communities cannot afford, so more suitable method for forecasting and detecting potential rockfalls is needed. For this study a specific location named Luka in Duće area and a part of old town centre of Omiš are selected as pilot sites.

Slope over Luka location is made of Eocene flysch, which is covered by a relatively thin and hard layer of breccia. Main component of flysch is marl, a rock material which is prone to weathering when submitted to atmospheric agents. As a result of weathering, surface formed of weaker marl is eroded with rain and the layer of harder breccia remains like “cantilever”. With time cracks start to form on the top of the cliff and parts of breccia start to fall off in large blocks. The cliffs over the town of Omiš are in the karstificated geological formation made mainly of limestone. Stabilizing the entire slopes in town area without localising potential threats would require considerable funding, which private owners and local community cannot afford, so a more cost-effective method to localise priorities should be found. One of them could be the proposed method that uses LiDAR technology.

LiDAR (Light Detection and Ranging) is an optical remote sensing technology used in Terrestrial Laser Scanners. TLS is often used to perform periodical monitoring in large landslide and rockfall areas. In this study Optech ILRIS-3D with enhanced range was used at both pilot sites. First scan with ILRIS-3D was made in September 2011, however at that time a serial malfunction was noticed. After repairment in Canada, scanning started again in April 2012 and it was repeated five times in a 3-6 month intervals to this day. The first scan for both pilot sites was georeferenced and it will be used as a reference scan for comparison of all future periodical monitoring at this location. Comparison of the two scans was made by using IM Survey module of Polyworks software.

Fig. 1 Comparison of 2011/09/27 and 2012/04/15 TLS datasets
As an example of comparison a large block removal was used to test the methodology of comparing sequential datasets (Fig. 1). On this figure the differences between two scans starting from 10 cm up to 4 m, from a 300 meters distant standpoint of the instrument, are clearly observed. With these results the morphology of the slope, block size and shape can be obtained very precisely and which can then be used in rockfall analysis. To detect smaller displacements of blocks (in the scale of millimetre to couple of centimetres) prior to its detachment, data should be acquired from standpoints closer to the cliff. However, this shortening of the range to the target raises the question of practical usage of this method for this and especially for even larger sites.

Except for detecting unstable blocks at steep slopes, this temporal model of surveying can certainly be applied for observing erosion process in soft rock (similar to marl in this area) or as an additional tool for creating rockfall inventory for this area. That would be a long-term project (minimum 10 – 20 years with yearly periodical scanning), however the results of which could be used for the purpose of detailed hazard mapping of the wider area than this pilot sites, and for sure help us to better understand the process of rock fall in this region.

In combination with previous methodologies, results obtained by a spectrometer could be used for better understanding some of triggering factors for rockfalls in these materials. In this project a non-destructive quantitative measurements of material reflectance were performed using portable field spectrometer TerraSpec 4 Hi-Res (ASD Inc., USA). All the measurements were made in the Geotechnical laboratory of the Faculty of Civil Engineering, Architecture and Geodesy. The measured wavelength region TerraSpec 4 ranges from 380 – 2500 nm which mean that covers a visible (400-700 nm) and near-infrared (700-2500 nm) regions.

The first laboratory tests with spectrometer suggest the relative quantity of the carbonate mineral group can be detected (in this area it consists mostly of calcite) and also there is a high possibility that they could be correlated with other testing procedures (such as calcimetry of XRD analysis). Therefore, spectrometer as portable device, unlike previously mentioned, can find it application in very fast in-situ measurements of those properties.

**Acknowledgement**

The authors would like to thank everyone involved in Japanese-Croatian project: Risk Identification and Land-Use Planning for Disaster Mitigation of Landslides, Japan Science and Technology Agency, Japan International Cooperation Agency and Ministry of Science, Education and Sport of Republic of Croatia.

**Address for correspondence:**

Author’s Name: Goran Vlastelica  
Institution: University of Split, Faculty of Civil Engineering, Architecture and Geodesy  
Address: Matice hrvatske 15, 21000 Split, Croatia  
Phone: +385 21 303 388  
E-mail: goran.vlastelica@gradst.hr
Dynamic Analysis of rock slope in Duće area

Chunxiang Wang(1), Hideaki Marui(1), Goran Vlastelica(2), Gen Furuya(3), Naoki Watanabe(1)

(1) Research Institute of Natural Hazards and Disaster Recovery, Niigata University, Japan
(2) University of Split, Faculty of Civil Engineering, Architecture and Geodesy, Split, Croatia
(3) Toyama Prefectural University, Faculty of Engineering, Toyama, Japan

With hundreds of investigated active and potential rockfall zones, the Duće and Omiš areas in the Dalmatian region ranks high on a risk scale for property and infrastructure destruction and potential for loss of life. Omiš and Duće areas are geologically different areas but with the same problem. Basically, cliffs over the town of Omiš are made of limestone, while the slopes in Duće area are formed in Eocene flysch formation. In the periods of earthquake and heavy rainfall, there is a problem with sudden rock falls. In both places, near the foot of cliffs and slopes there are residential areas with numerous dwellings. Houses and inhabitant lives are jeopardized with the potential fall of a very large stone blocks.

In this study, because of shortage of the digital elevation data in the Omiš area, we just analyzed the behavior of the rock slope and rockfall in the Duće area. The analyses of static and dynamic rock slope stability and the dynamic movement process of rockfall in the Duće area are were performed using the distinct element code UDEC (Universal Distinct Element Code). When the stability of the rock slope is controlled by movement of joint-bounded blocks, the use of discontinuum discrete-element codes, which allow one to conduct fully dynamic analyses under plane-strain conditions, are more appropriate than the continuum codes. The stability analyses have been carried out in two stages for predicting the behavior of the rock slope and rockfall. First, an initial static loading is applied in the numerical model. Second, a seismic loading is applied to simulate dynamic earthquake conditions.

An important issue in the evaluation of potential hazard related to rockfalls is the quantitative prediction of the traveling distance of the falling blocks, which is necessary to identify the potentially endangered houses. This information is also fundamental for the design of appropriate defensive works, which are intended to reduce the potential impact of the landslide on the population and facilities potentially at risk. Obtaining a reliable estimate of this quantity is complicated by the interaction of the rocks and the slope surface that can affect the behavior of the blocks at the impacts. In this study, the dynamic movement trajectory for a rock block falling on the Duće slope is simulated.

The study in this paper provides an illustration of how the geo-mechanical properties of a rock mass can be integrated in a discontinuum rock slope model. This model aims to help to better understand the dynamics of the rockfall in the Duće area when subjected to static and dynamic loads.

Address for correspondence:
Author’s Name: Chunxiang Wang
Institution: Research Institute of Natural Hazards and Disaster Recovery, Niigata University
Address: Ikarashi-Ninocho, Nishi-ku 8050, 950-2181 Niigata, Japan
Phone: +81-25-262-7059
E-mail: wangcx@gs.niigata-u.ac.jp
Comparison of Terrestrial Laser Scanners for slope stability monitoring

Boško Pribičević\(^{(1)}\), Almin Đapo\(^{(1)}\), Branko Kordić\(^{(1)}\), Luka Babić\(^{(1)}\), Marin Govorčin\(^{(1)}\), Goran Vlastelica\(^{(2)}\)

\(^{(1)}\) Faculty of Geodesy, University of Zagreb, Kačićeva 26, Zagreb, Croatia
\(^{(2)}\) University of Split, Faculty of Civil Engineering, Architecture and Geodesy, Split, Croatia

Terrestrial laser scanning (TLS) is a technology that allows non-contact determination of large amounts of points in a relatively short time. Although the basic principle of measurement is known, there is no universal terrestrial laser scanner that could perform all types of measurements. Therefore, there are classifications of terrestrial laser scanners according to principles that are used for distance measurement (pulse, phase shift), as well as classifications of TLS according to laser beam deflection method to camera, panoramic and hybrid scanners. Because of various classifications of TLS's, it is not possible to directly compare technical specifications of instruments which make it difficult for customers to choose the right scanner for specific projects. Since there is no standard, it is necessary to investigate terrestrial laser scanners to obtain independent accuracy/precision estimates and develop standardized calibration models and procedures. Thus, in this article two terrestrial laser scanners from different manufactures were tested: Faro Focus 3D and Optech ILRIS. Instruments used in this research vary according to range measurement as well as deflection of the laser beam principle. In the experiments identifying distance measurement errors which occur due to erroneous laser beam reflection from some specific material or specific color was concentrated on.

Measurements with terrestrial laser scanners as well as other surveying methods contain errors that are caused by a variety of sources and influences relevant to all processes of determining spatial data. TLS's consists of a series of optical, electronic and mechanical parts, which are all a potential source of errors. If a TLS is used in highly specialized conditions such as landslide surface movements or surface deformation analysis, comprehensive knowledge of all error sources is required for correctly interpreting collected data. Errors in TLS measurements can be divided into four classes: instrumental, object related, environmental and methodological errors. Therefore, the performed research in which investigation on standard parameters of laser scanners (accuracy, resolution, time) and some features of the "real" conditions of measurements that depend on the selection of laser scanner (precision measurements at different distances, the time required to collect detailed points, the intensity of the return signals from different materials of the subject) were performed. Laboratory tests were performed on the Faculty of Geodesy in Zagreb, however in addition to laboratory tests geodetic measurements on the field during a period of one year were also performed. For the field tests a location of unstable block in the area of old town Omiš suitable for recording was determined and measured. Collected data and preformed analysis will be further presented in this article.

Terrestrial laser scanner Faro Focus 3D is based on phase shift distance measurement method with a range of 120 m from targets having a minimum of 90% reflectivity. Field of view of the afore scanner is 360x305 degrees. Accuracy of distance measurement is 2 mm at 25 m and it has an integrated camera with a resolution of 70 MPx for the entire field of view. Scanner is controlled by touch screen directly on the device or remotely (notebook, PDA, Smartphone) using Wi-Fi and the collected data is stored on an SD card. Faro Focus 3D, also has a dual-axis compensator allowing for setting up of the scanner like a total station.

Optech Iris 360 is a pulse based distance measurement method scanner. It has an accuracy of about 7 mm at 200 m. This type of laser scanner can determine distances up to 1500 m depending on reflectivity of object. Its field of view is 40x40 degrees but it can be extended by using a pan/tilt base to 360x220 degrees. The scanner is controlled by notebook via Ethernet cable or by a remote device using Wi-Fi network. Field data can be stored in an internal or external memory.

Address for correspondence:

Author’s Name: Marin Govorčin
Institution: Faculty of Geodesy, University of Zagreb
Address: Kačićeva 26, 10000 Zagreb, Croatia
Phone: +385955110584
E-mail: mgovorcin@geof.hr
Application of Terrestrial Laser Scanning and Sensor Networks for Landslide Monitoring

Vladimir Pajic, Miro Govedarica, Milan Vrtunski
Faculty of Technical Sciences, Novi Sad, Serbia

Monitoring landslides with terrestrial laser scanning (TLS) is currently a well-known technique [3]. TLS is mainly used for landslide investigation to create accurate and precise high resolution digital elevation models (HRDEM) in raster grids or triangulated irregular networks (TINs), which are 2.5D representations of the topography, or in true 3D point clouds with a high density of information. Monitoring of a landslide is performed through a number of TLS surveys in the defined time intervals. For every survey following procedure have to be performed in order to produce HRDEM:

1. the registration of individual scans into single point cloud,
2. filtering of points in order to separate laser points on the terrain surface from topographically irrelevant points
3. interpolation and creation of HRDEM [4].

To investigate the multitemporal evolutions of the landslide, the HRDEMs from the different surveys should be compared in order to produce vectors between two points (or common areas) or distances between two data sets (point to surface comparison) [3]. In order to avoid false conclusions, it is necessary to define a strict programme of surveying and data processing methodologies that can be repeated systematically at different times, always avoiding to change any detail of the procedure. Environmental conditions at the landslide such as dense vegetation or rugged terrain can introduce the errors in generated HRDEMs which also could lead to false conclusions [1, 2].

The presented methodology will be used for monitoring of a small landslide on the northern slopes of Fruska Gora near the city of Novi Sad. The landslide has a rectangular shape, it is about 70 meters long and 30 meters wide, the slope of terrain is about 11 degrees and it is covered with sparse low vegetation. The scanning will be performed using Leica ScanStation P20. According to landslide geometry and maximal scanner range of 120 meters, 3 scanner positions (Fig. 1) will be required to cover complete area with good point density. The coordinates of 4 targets (Figure 1.), located on stabilized points at every corner of the landslide, will be used for the registration and georeferencing of the point clouds. Leica Cyclone will be used for registration and georeferencing, as well for the removal of points outside of landslide area. The filtering of points and generation of terrain models will be performed in TerraScan and TerraModeler. ERDAS Imagine will be used to calculate of differences between HRDEMs from different surveys.

Along with TLS surveys, a sensor network consisting of a total station and a set of GNSS receivers has been set up on the landslide [5]. Total station, placed over stabilized point at the foothill of a landslide, periodically, measure the positions of reflectors distributed over the landslide body. A set of high-accuracy GNSS receivers have been mounted on landslide body and in its vicinity, conducting continuous observations. Processing and analysis of GNSS measurements can produce high accuracy data (5-10mm). Leica GeoMoS software will be used to control the network, collect the measurements and perform data analysis. Scanner positions and target locations will be also monitored by the network in order to detect any change of scanning geometry. That information will be important in order to correctly process the point clouds and interpret the results.

The measurements collected by TLS and the other sensors will be used together for the analysis of landslide process. Each method will be controlled by the other two methods in order to improve reliability of the results. In the next step of network development, the other types of sensors, like meteorological sensors, inclinometers, piezometers or extensometers, will be included. Those measurements will enable better understanding of the reasons of any detected movement and improvement of the prediction of failure.
Fig. 1 Scanner (red) and target (yellow) locations

References

[1] M. Barbarella, M. Fiani, Monitoring of large landslides by Terrestrial Laser Scanning techniques: field data collection and processing. Accepted for publication on EuJRS (2013)


Address for correspondence:
Author’s Name: Vladimir Pajic
Institution: Faculty of Technical Sciences, Novi Sad
Address: Trg Dositeja Obradovica 6, 21000 Novi Sad, Serbia
Phone: +381637188904
E-mail: pajicv@gmail.com
Characteristics of sliding displacement of Kostanjek landslide in Croatia

Hiroyuki Yoshimatsu (1), Eisaku Hamasaki (2), Hideaki Marui (3), Takeshi Kato, Chunxiang Wang (3), Martin Krkač (4), Snježana Mihalić Arbanas (4)

(1) Kawasaki Geological Engineering Co. Ltd., Tokyo, Japan
(2) Advan Technology Ltd., Sendai, Japan
(3) Research Institute for Natural Hazards and Disaster Recovery, Niigata University, Niigata, Japan
(4) Faculty of Mining, Geology and Petroleum Engineering, University of Zagreb, Croatia

In Kostanjek, the amount of sliding displacement of the tertiary creep was observed in extensometer that was installed on the slip surface in tunnel of the landslide center area from December 2011. On the other hand, the amount of sliding displacement by extensometer that was placed in a depression zone of the head area delayed about three months, and is also a less than half the amount. It is generally the amount of sliding displacement of the landslide head's exists larger and first appears than the other locations. The amount of displacement analysis was performed by the finite element method for dividing by triangular element network node spacing 40m landslides area to consider the amount of displacement of the landslide central portion is large (Fig 1). Dissipation stress becomes extremely large at the point where a sudden change of terrain that changes from 90m to 8m below in the landslide layer thickness. Also in the point of moving layer thickness is thin, shear resistance is reduced from that vertical load is small. We can report that the amount of landslide displacement increases at this point.

Fig.1 Analysis of amount of landslide displacement

Address for correspondence:
Author’s Name: Hiroyuki Yoshimatsu
Institution: Kawasaki Geological Engineering Co. Ltd.
Address: 2-11-15 Mita, Minato-ku, 108-8337 Tokyo, Japan
Phone: +81-3-5445-2082
E-mail: yoshimatsuh@kge.co.jp
Slope stability analysis and mitigation measures in the area of the Sibiu-Orastie motorway viaduct

George-Catalin Silvas
University of Bucharest, Faculty of Geology and Geophysics, Bucharest, Romania

The Sibiu-Orastie motorway will be the fastest way to go from the south part to the east part of Transylvania. It is the most complex motorway construction project in Romania since now. The motorway has a length of 22,109 km, but the most spectacular structure is a viaduct with a length of 1,01 km. It is not spectacular only because of the length but because of the complexity of the structure. The scope of the viaduct is to make a junction between two slopes with approximately the same elevation. But to do so the first step is to make a very rigorous geotechnical investigation program.

Geographically, geo-morphologically and geologically speaking, in a general way, the site is localized in the Transylvanian Basin. The geology of the site is a result of a sinking of the crystalline-Mesozoic relief, which took place from the beginning of the superior cretaceous until the Pliocene. Hence the geology is represented by pre-tertiary bedding structured in the crystalline bedrock and a Mesozoic sedimentary covering, and over them lie the tertiary formations. The tectonics reveals that Transylvanian Basin is a post-tectogenetic basin and it has formed at the end of the Jurassic.

In a specific way, the geology of the site is represented by quaternary deposits and pannonian deposits. The quaternary deposits consist of silty clays and the pannonian deposits consist of clays, marly clays and some sand intercalations, information provided by the geotechnical drillings made on the site. The presence of the silty clays raised some questions regarding the stability of the slopes. Regarding the landslide triggering it was not the question “How?” very important, but the most appropriate question was “When?”. Since it was the possibility that the structure of the viaduct would influence the stability of the area in negative way a slope stability analysis was undertaken.

After the geotechnical investigation program was finished, the laboratory results for the quaternary deposits were not so good. This was the first factor that could trigger landslides in the area. Another factor was the ground water table of the site. Because of the V shape of the site, the ground water table runs through the geological formations, and mostly in the rainy seasons at the base of the two slopes a marsh was to be formed. Another factor was, of course, the human activity on the site in the construction phase. As the main factors were identified the instability problem in the area was certain.

The stability analysis results confirmed that the two slopes have some instability problems. Because of the poor geotechnical parameters of the clayey soils there was a possibility of landslide triggering. The triggered landslides would affect the viaduct’s two abutments.

The stability analysis gave information that the areas of the two abutments were to be affected by landslides. Hence some mitigation measures were to be undertaken to assure the stability of the areas. The first measure was to increase the length of the viaduct and the second one was to excavate the instable geological layers completely in the areas of the two abutments. These measures assure the stability of the two slopes in the interest areas.

Address for correspondence:
Author’s Name: George-Catalin Silvas
Institution: University of Bucharest
Address: Novaci 8, 051728 Bucharest, Romania
Phone: +40727780531
E-mail: georgecatalinsilvas@yahoo.ro
Urgent rock fall stabilization by planned demolition

Sabid Zekan, Šefika Alajbegović, Alen Baraković
University of Tuzla, The Faculty of Mining, Geology and C. Engineering, Bosnia and Herzegovina

In the area of the village Martin-Brod, Bihać, there was a rock fall, which caused the collapse of the outbuilding on a family farm on a steep slope. The rock fall occurred on December 16 2012, at 12:30. A stumbling block with a volume of about 1 m$^3$, while it was rolling down the cliff, destroyed some small oak trees and passed between other trees and hit into a wall of the outbuilding with a significant damage.

The location of the rock fall is the right bank of the river Unac in the village Martin-Brod. It is a slope with a changeable inclination from 15$^\circ$ to 40$^\circ$. The slope is covered by small trees and there are some stone blocks which damaged the trees. The other part of the slope has the characteristics of a scree, so there are a lot of stone blocks deposited during the rolling to the river valley.

On the upper part of the slope there was a large block, dimensions 7.0 x 3.5 x 3.5 m, which was considered as a potential risk to make harmful rolling to the houses in the valley and also a lot of smaller blocks with a volume of 1-5 m$^3$, which lie around it. The estimated volume of the unstable mass is approximately 15.0 x 100.0 x 2.0 meters.

Fig. 1 Trajectory of the rolling stone blocks and stabilization measures

Fig. 2 The biggest stone block and a lot of unstable ones around them
The cause of the rock fall occurrence is a process of decomposition of the rock mass at the site of geological discontinuity. The upper lithological unit consists of firmer limestones than the lower one. Firmer limestones break off and make large blocks ready for rolling down the slope. The broken blocks of rock mass moved down the slope under the force of gravity as an uncontrolled process.

Stabilization measures aim to protect people and properties from rock falls. Stabilization measures should be done in two phases:

- Works to prevent stone blocks to reach the village,
- Provocative demolition of the stone block, 7.0 x 3.5 x 3.5 m, on the slope.

Trajectory of stone blocks moving can be divided into two parts, accelerating and retardation part. The accelerating part of the trajectory has the length of about 100 meters and 40° of inclination, and the retardation part has the length of approximately 300 meters and 15°-20° of inclination. In the retardation part of the trajectory there are also small oak trees as a factor of stabilization.

The concept of the prevention was reducing the velocity – kinetic energy of the stone blocks. It was possible to make defensive barriers in the form of gabion wall and stabilization trenches. A gabion wall is planned at a foot of the accelerating part of the slope. The length of the gabion wall is 15 meters and the height is 2,0 meters. The purpose of the gabion wall is to stop all the rolling blocks. An additional defensive barrier is stabilization trenches and it has a function of a second or reserve barrier. It has been planned to make two trenches. The first one should reduce the kinetic energy of rolling blocks and the purpose of the second one should be the final stopping of blocks. The width of the trenches is 3,0 meters and the denivelation height is 1,5 meter. The distance between the trenches is 3,0 meters.

Provocative demolition of the stone block should be done by means of explosive. The amount and type of explosive has been determined. The optimal amount of explosive and points of initiation have also been determined. The initiation of explosives can be done from a safe distance, 100 meters northwest of the location.

Address for correspondence:
Author’s Name: Sabid Zekan
Institution: University of Tuzla, The Faculty of Mining, Geology and C. Engineering
Address: Univerzitetska 2, 75000 Tuzla, Bosnia and Herzegovina
Phone: + 387 61 562 277
E-mail: sabid.zekan@untz.ba
Engineering geology process induced by salt exploitation in Tuzla town

Toni Nikolić
Federal geological survey, Sarajevo, Bosnia and Herzegovina

Many landslides over centre of Tuzla arise like consequence of salt exploitation in Tuzla town, what include subversion more than 2700 objects. Velocity of subsidence was measured from 1914. and till now on area with maximal deformation is more than 14m, what is about 20cm/year. After 2002. exploitation was stop on this area but sinking and sliding, is still active. On Fig. 1 horizontal movement of surface is presented, where the red colour present the most hazard on surface and objects on them. Red arrows show direction of horizontal move soil, related for topographic of area and try to become stabile on the bottom of hill.

Fig. 1 Overall subsidence occurred in the area of Tuzla along the period 1956-2003

The highest problem is the road, which gone cross landslide zone and which connect hospital with town. Even he was reconstructed many time, landslide break it. Sliding zone is so deep, because of sink effect and is not possible easy solve problem just on the surface. Rain and underground water make extra problem and each time, after long rain period push soil slide over the hill. Soil is presented usually by different kind of clay and marl, what is good base for landslide activation. Over this work, will be presented this specific case landslide induced by anthropogenic factor.

Address for correspondence:
Author’s Name: Toni Nikolić
Institution: Federal geological Survey
Address: Ustanička 11, 71210 Ilidža – Sarajevo, Bosnia and Herzegovina
Phone: +387 61 331 615
E-mail: nikolic_t@yahoo.com
Example landslide remediation on a railroad track near Banja Luka

Nedim Suljić

University of Tuzla, Faculty Mining-Geological-Civil Engineering, Tuzla, Bosnia and Herzegovina

On the railway line near Banja Luka, was created by a landslide on the slope of which is the average slope of about 30°, if the exempted local variations. On the appearance of the field, except the process moving, and influenced by human activity (filling materials when building railway line) so that the slope is characterized by rapid movement of slope on a very short distance.

Landslide is a length of about 20 m, a width of in frontal part of the 10 m while in the middle part is 8 m. The deepest sliding surfaces, according to analyzes conducted, is 3 m jump on top of the landslide is 1 m. Increase sliding mass in the lower part did not was observed during the field visit and during the geotechnical investigation works.

On the basis of the established general properties of landslides, then of established causes of sliding and mechanism as well as the identified major factors which make landfall in the periodic activities, with engineering-geological aspects, have been proposed repair measures making five drainage or stone ribs vertical to the axis of the railroad with the construction of retaining reinforced concrete wall length of 30 m. Height planned retaining wall is 3,50 m.

Behind the reinforced concrete retaining wall needs to build drainage system. Drainage system has to accept water from the drainage ribs and that the revision pane carried away outside wall. The collected water is prefabricated concrete channels must be controlled drain to a nearby canal. As part of the remedial measures necessary to clean clogged concrete channel for the reception surface water above the railway (parallel to the railway line). So make be occasional and permanent surface water unhindered channeled toward reinforced concrete omission in the hull railway and further controlled led to a nearby channel.

After implementing the investigation works and finished project documentation approached rehabilitation of landslides. Works to repair landslides were completed during the 2009th year, and have not was observed moving soils on the locality. On the basis that we can conclude that it is project design was successful and the method works on rehabilitation of landslides.

Address for correspondence:

Author’s Name: Nedim Suljić
Institution: University of Tuzla, Faculty Mining-Geological-Civil Engineering
Address: Univerzitetska 2, 75000 Tuzla, Bosnia and Herzegovina
Phone: +387 61 721 531
E-mail: nedim.suljic@untz.ba
WORKING GROUP 2: FLASH FLOODS AND DEBRIS FLOWS
INVITED LECTURE

Water related risks

Ognjen Bonacci
(1) University of Split, Faculty of Civil Engineering, Architecture and Geodesy, Split, Croatia

Water is the topic of the day on the international scene, because of a critical situation in numerous countries and regions. Fresh water is perhaps the single most important resource on Earth. World is faced with growing vulnerability of society to natural and anthropogenic water disasters. The growing frequency and magnitude of extreme environmental events world-wide has intensified research interest in natural disasters as well as regional vulnerability and response capabilities.

The rapid alternation of flood and low flow (drought) events during recent years has led to fears that the dynamics of the hydrological cycle has intensified probably as a consequence of global warming. Scientists predicted that in the warmer, wetter world the northern part of the northern hemisphere will likely see more storms, while some continental areas might have drier summers and more risk of drought. Sea level rise fed in part by melt-water from glaciers and ice caps could inundate small islands, flood coastal lowlands, and erode sand dunes. Along with this, extreme high-water levels may occur with increasing frequency.

At present international scientific community is faced with an environment ecologically, climatically, geologically, and due to these socially and politically, so fragile and vulnerable to risks of floods, droughts, landslides and water and soil pollution. Now it is hence the decisive moment to start a process of co-ordinated international multi- and interdisciplinary research and other activities covering knowledge and information exchange.

Water related natural disasters equally affect countries large and small, rich and poor, unrespectable of their political stance, and they present the formidable barriers to national, regional and global development. There is a growing consensus that they must be viewed as a world-wide problem, one that requires concerted global action. Without this social mandate, our scientific and technical progress cannot impart its full benefit to those at risk. While water related natural hazards are not controllable, the scientific community has a greatly improved ability to alter society’s vulnerability to these hazards by taking countermeasures to reduce their impact. Paper uses holistic approach to water related disasters with special reference to floods and droughts.

Address for correspondence:
Author’s Name: Ognjen Bonacci
Institution: University of Split, Faculty of Civil Engineering, Architecture and Geodesy
Address: Matica hrvatske 15, 21000 Split, Croatia
Phone: +385 21 303 340
E-mail: obonacci@gradst.hr
Morphometry of Red Lake using LiDAR and SoNAR technology

Ivo Andrić\(^{(1)}\), Ognjen Bonacci\(^{(1)}\), Goran Vlastelica\(^{(1)}\), Yosuke Yamashiki\(^{(2)}\)

\(^{(1)}\) University of Split, Faculty of Civil Engineering, Architecture and Geodesy, Split, Croatia,
\(^{(2)}\) Kyoto University, Graduate School of Advanced Integrated Studies in Human Survivalbility, Japan

Red Lake in the Dinaric karst (Croatia) is the exceptional karst phenomena, world wide known for its beauty and extreme depth. Even so, through the history of Red Lake’s research there were many controversies in the conclusions and the theories concerning its genesis, geomorphology and hydrology. This work has for a goal to give an overview of existing findings about Red Lake as well as to present the newest research results won with the help of emerging technologies based on LiDAR (Light Detection And Ranging) method and hydro acoustics. For the first time the precise morphometry for the Red Lake is given which is known to be one of the deepest karst lakes in the world. The measurements took place during September 2013. New generation of equipment developed to advance the geoscientific research has been deployed during the field work and the gathered data enabled the analysis which led to a new understanding of the lake’s morphology.

The LiDAR survey resulted with obtained set of data "cloud point", where each point has a defined position in space. The cloud point was filtered with respect to outliers and noise. Data collected using LiDAR methods provide accurate digital elevation model, which can be used in further analysis and modelling.

For the purpose of underwater investigations of the lake the remotely operated underwater vehicle, commonly referred to as an ROV was deployed, equipped with a HD camera, precision compass with gyro and SoNAR (Sound, NAvigation and Ranging) for hydro acoustics survey. ROV can accurately measure the depth of the dive and the geometry of the horizontal sections in spherical coordinates. Images are recorded at different depths with the sonar device placed on the ROV. Operating frequency of the sonar is 670 kHz and the power of transmitted signal is 23 dB. Such configuration of the device can provide registration of echo at distances up to 600 m in ideal conditions. The results gave a new insight into geometry of the deepest karst lake in the world as well as into functioning of the karstic lake.

The further research on Red Lake involves the regular LiDAR scanning of the lake’s shores above the water surface in order to determine the amount of fallen material between the two recordings as well as the rate of collapsing process. The research will also consist from periodical temperature and dissolved oxygen records and continuous monitoring of water turbidity. It is from crucial importance to expand the scope of future measurements and to simultaneously measure the hydrological parameters in Blue and Red Lakes with the option to monitor other karstic water phenomena in the vicinity. An insight into the regional direction of circulation of groundwater would be possible with adequate spatial distribution of deep piezometers in the study area.

The availability of new technologies in hydrological and geomorphological measurements opens up new possibilities in the study and monitoring of the karst aquifer as well as karst phenomena such as Red Lake. Every new research work and scientific results based on measurements using modern technology enrich and complete the overall knowledge in karst hydrology. This should be a guideline in the future scientific research of the functioning of Red and Blue Lakes near Imotski.

Acknowledgement

This work was created as part of a joint international project of the Croatian Ministry of Science, Education and Sports and the Japanese Cooperation Agency JICA entitled "Risk identification and land use planning for disaster mitigation in landslides and floods in Croatia." Special thanks goes to the company Neptun-SUB Ltd. (Šibenik, Croatia) for the transfer of equipment and professionals free of charge for the academic purposes. The authors are especially grateful to the cavers from Caving Club Imotski for the technical support. Without their help, the field research would not be possible. The authors are grateful for the financial support provided by Imotski Tourist Board.

Address for correspondence:

Author’s Name: Ivo Andrić
Institution: University of Split, Faculty of Civil Engineering, Architecture and Geodesy
Address: Matice hrvatske 15, 21000 Split, Croatia
Phone: +385 21 303 412
E-mail: ivo.andric@gradst.hr
Influence of extreme climate conditions on runoff

Kisić Ivica, Bilandžija Darija, Bogunović Igor

University of Zagreb, Faculty of Agriculture, Department of General Agronomy, Zagreb, Croatia

This paper will present research results that have been collected during two years of research in the erosion experimental field Freivogel’s Hill near Daruvar. The aim of this paper is to present soil erosion by water at different tillage methods in extremely rainy 2010 when double crop was grown on the trial field (wheat + soybean) and extremely dry 2012 when maize was grown on the trial field. Experimental field consists of six variants, which differ according to the type, number, depth and direction of tillage and the variants of the experiment are as follows: I variant - the standard control version by USLE (Universal Soil Loss Equation) - black fallow (plowing to a depth of 25-30 cm along the slope), II variant - plowing up/down the slope (plowing to a depth of 25-30 cm and sowing carried out along the slope), III variant – no-tillage (sowing is done in the mulch along the slope), IV variant - plowing perpendicular to the slope, plowing to a depth of 25-30 cm and sowing are carried out perpendicular to the slope, V variant - very deep plowing perpendicular to the slope (plowing to a depth of 50 cm and sowing are carried out perpendicular to the slope) and VI variant - subsoiling + conventional tillage perpendicular to the slope (plowing to a depth of 25-30 cm, subsoiling to a depth of 50 cm and sowing are carried out perpendicular to the slope). The average annual temperature in a multi-year period from 1960 to 1999 is 10.7 °C and annual precipitation is 889 mm. In 2010 mean annual air temperature was at the multi-annual average (10.9 °C) and in 2012 it was higher by 1.1 °C in relation to the multi-annual average (11.8 °C). Total amount of precipitation recorded during 2010 was 1132 mm which is much higher compared to the multi-annual average, while in 2012 the precipitation was by 100 mm lower compared to the multi-annual average (789 mm). Based on the above data, it was expected that the soil erosion by water will be much higher in 2010. The measured values indicate that the erosion was much more pronounced in 2012, reflecting among other things the influence of weather conditions during these years. The biggest loss of soil by erosion in both years of research was recorded at the standard control version by USLE which was treated and uncultivated, bare soil. The losses were several times higher than the soil loss tolerance (T value) which is estimated at 10 t/ha/yr. In 2010 when double crop was grown the losses amounted to 36.03 t/ha, and in 2012 when maize was grown the losses were 96.59 t/ha. In the variant of tillage (plowing to a depth of 25-30 cm) and sowing along the slope in the cultivation of wheat and soybean the recorded loss of soil by erosion was 1.56 t/ha and in the cultivation of maize the recorded loss was 46.20 t/ha. In both years in the variant with no-tillage the losses were negligible and amounted to 0.56 t/ha (2010) and 0.31 t/ha (2012). Tillage (plowing to a depth of 25-30 cm) and sowing perpendicular to the slope shows a sufficient efficacy in protecting the soil from water erosion in both years of research: in 2010 the erosion amounted to 0.74 t/ha and in 2012 it was 9.03 t/ha. In the cultivation of wheat and soybean and the variants with very deep plowing perpendicular to the slope, the erosion was 0.73 t/ha and in the cultivation of maize it was 11.18 t/ha. Subsoiling + plowing and sowing perpendicular to the slope in the cultivation of studied crops effectively protects the soil and reduces erosion to only 0.43 t/ha (2010.) and to 7.57 t/ha (2012) in the cultivation of maize. This indicates that during the studied years the vegetation (crops) and applied tillage methods had a more important role in preventing the occurrence of erosion processes than the total amount of precipitation during the studied years. This indicates that we can mitigate the impact of extreme weather and climatic events that are increasing in frequency by appropriate agro-technical tillage methods. Unfortunately, these climate changes cannot be prevented.

Keywords:
soil erosion by water, rainfall, soil tillage, soil loss tolerance, double crop, maize

Address for correspondence:
Author’s Name: Ivica Kisić
Institution: University of Zagreb Faculty of Agriculture, Department of General Agronomy
Address: Svetoslimunska cesta 25, 10000 Zagreb, Croatia
Phone: +385 1 239 39 35
E-mail: ikisi@agr.hr
Groundwater behaviour in the Kostanjek landslide, western part of Zagreb, Croatia: geochemical constraints from water and rock samples

Naoki Watanabe(1), Satoshi Yamamoto(3), Martin Krkač(2), Gen Furuya(4), Chunxiang Wang(1), Snježana Mihalić Arbanas(2)

(1) Research Institute for Natural Hazards and Disaster Recovery, Niigata University, Niigata, Japan
(2) Faculty of Mining, Geology and Petroleum Engineering, University of Zagreb, Zagreb, Croatia
(3) Accutech Inc., Niigata, Japan; (4) Faculty of Engineering, Toyama Prefectural University, Japan

Groundwater behaviour, in many cases, is an important factor for the occurrence and activity of landslides. Hydrochemical characteristics of groundwaters reflect compositional properties of solid phases of the parent rocks through which groundwater flows and also provide signatures as natural tracers to better understand groundwater migration. During the September 2011 and June 2012, one sample of spring water, seven samples of stream water, 11 samples from the mining tunnel (entrance of the tunnel and inner part of tunnel) and 74 ground water samples from private wells in the Kostanjek area were collected for hydrochemical and isotopic analyses. The pH, EC and temperature of all samples were determined in the field, while Na, NH4, K, Mg, Ca, Sr, HCO3 and CO3 as alkalinity, Cl, NO3 and SO4, were analysed in the laboratory of the Research Institute for Natural Hazards and Disaster Recovery at Niigata University. On the basis of hydrochemical data we have classified into four water types by cluster analysis as follows; (1) Type-A is typical Ca-HCO3 type water, (2) Type-B is weaker water in Ca-HCO3 component than type-A, (3) Type-C is Mg-rich Ca-HCO3 type water, (4) Type-D is Mg-Ca-HCO3 type water. Both type-A and type-B waters are predominately distributed over the research area and are closely related to the shallow aquifer lithologies. Type-A waters are derived Ca and HCO3 from marl aquifers. Type-B waters are formed by the mixing of Type-A water with dilute subsurface water from soil zones where soluble solids were removed during chemical weathering processes. Type-C waters are limitedly distributed around the eastern margin of the Kostanjek landslide and Type-D waters gush out from fissures in the dolomite outcrop in the inner part of the tunnel. In particular, Type-D waters are more enriched in Mg and depleted in Sr than type-C waters. It means that the dolomite is major source of Mg in waters from this area. On the other hand, isotopic compositions of δ18O and δD of all waters are meteoric water of origin even if type-D waters are depleted in δ18O and δD comparing with others. The depleted type-D waters in isotope compositions suggest that these are recharged in the higher area of the northern mountain, western part of Mt. Medvednica, and migrate through dolomite aquifer to the depths of the landslide mass. Type-C waters from shallow aquifers in the landslide also include Mg to some extent even though there is no dolomite layer in the landslide mass and the massive dolomite is distributed in more than 1,000m north away from this area and also underlies in more than 200m depth beneath the landslide mass. Then type-C waters show to be slightly depleted in δ18O and δD comparing with type-A and type-B waters. It seems that type-C water is influenced by isotopically depleted type-D water from the dolomite aquifer.

Ortolan (1996) suggested that artesian aquifer related to Badenian limestone and Triassic dolomite, underlays Sarmatian-Pannonian marly sediments and Kostanjek landslide. According to hydrochemical characteristics, e.g. graphical plots of Mg/Ca vs. Sr/Ca ratios of waters, and isotopic compositions, it is clear that type-C waters are originally formed by mixing of common type-A and type-B waters with type-D waters derived from the dolomite aquifer. Therefore, it is most likely that type-D artesian waters from the deep dolomite aquifer continuously inject into shallow aquifers around the eastern margin of the landslide. Such injection of deep artesian waters has an impact upon the groundwater behaviour in the landslide mass and is also one of the key factors controlling the landslide susceptibility. In planning the counter-measures by groundwater drainages for the effective reduction of pore water pressure in the Kostanjek landslide, it is useful to identify the source of groundwaters based on hydrochemical characteristics, especially Mg-rich waters from the artesian aquifer.

Reference


Address for correspondence:
Author’s Name: Naoki Watanabe
Institution: Research Institute of Natural Hazards and Disaster Recovery, Niigata University
Address: 2-8050 Ikarashi, Nishi-ku, 950-2181 Niigata, Japan
Phone: +81-25-262-7059; E-mail: jibanken@cc.niigata-u.ac.jp
Assessment of Rainfall as a trigger on Grohovo Landslide

Maja Oštrić(1), Josip Rubinić(2), Kyoji Sassa(3), Kaoru Takara(4)

(1) Croatian Waters, Rijeka, Croatia
(2) Faculty of Civil Engineering, University of Rijeka, Croatia
(3) International Consortium on Landslides and Kyoto University, Japan
(4) Disaster Prevention Research Institute, Kyoto University, Japan

Different phenomena cause landslides. These phenomena can be grouped as preconditions, preparatory, and triggering factors. Triggering by rainfall or more general hydrological triggering is commonly known as one of the principal natural landslide initiation mechanisms.

The Grohovo landslide in Croatia, the biggest landslide on the Croatian coast, is selected as one of the study areas within Japanese-Croatian research projects that were initiated in 2009. To investigate the impact of rainfall as a trigger in reactivation of the Grohovo landslide in 1996, we performed rainfall data analysis. For the analysis of long-term rainfall data (or antecedent, "pre-event") we used data of monthly precipitation records at Rijeka station for the period from 1948 to 2011. For the short-term rainfall analysis, we had daily precipitation for the period from 1993 to 2006 of the same station as well as the continuous (i.e., every 5 min) rainfall record for the 3 month period that preceded landslide reactivation (September 1st-December 5th 1996). Although data of monthly discharge of Rijecina River exist from 1948, measurements for a profile of Grohovo in the period 1995-1997 are missing. However, during 1996, when landslide reactivation occurred, several hydrological stations located upstream from the Grohovo landslide and the Valici reservoir, were active.

By analyzing the monthly precipitation data for the Rijeka station in a 65 yr. period (1948-2011), it was found that landslide reactivation was probably caused by cumulative rainfall in the rainy period during October and November (Oštrić et al. 2011). It is clear that in 1996 a very dry summer period (with precipitation lower than average for the 65 yr. period) was followed by a very wet period (exceeding average values by 75 %). However, by analyzing daily and hourly data of the same period (September-December 1996), no significant single event was observed in that period. The return period of the observed 2, 3, and 4 cumulative monthly rainfall in 1996 was 19, 24, and 15 years respectively. Short-term data analysis showed a much higher probability of occurrence, i.e., less than a 2-year return period. The analysis indicated that antecedent conditions are more important for the reactivation of a landslide or landslide initiation than short-term rainfall intensities alone.

Despite a significant amount of recorded rainfall that preceded the re-activation of the landslide, on the critical days (the 5th and 6th of December, 1996), very low values of maximum daily flow were recorded. It should be noted that at all the mentioned profiles, in mid-November 1996, maximal flows for that year were recorded. But even these maximum annual recorded flows were in the range of the average events. From the presented data it can be concluded that the surface runoff of Rijecina River did not have an impact on the landslide re-activation.

Due to the low permeable properties of flysch material and to the behaviour of landslides in the same or in similar clay rich materials, it is reasonable to assume that cumulative rainfall for a longer period has a more important role in landslide formation and reactivation. This is also in accordance with previous investigations that generally emphasized the importance of soil moisture in landslide initiation of low permeable terrains (Pasuto and Silvano 1998; Glade et al. 2000; Jakob and Weatherly, 2003; Aleotti 2004, Guzzetti et al. 2008). Some argue that groundwater levels and soil moisture conditions cannot be considered as triggers, but as preparatory factors (Reichenbach et al. 1998, Guzzetti et al. 2008). However, antecedent rainfall that influences both groundwater levels and soil moisture can be used to determine when landslides are likely to occur. The main difficulty is that the definition of the period over which rainfall accumulates and the considered periods vary from 3 days to 4 months (Cardinali et al. 2006). In our study, antecedent conditions of longer periods (60-120 days) showed to be the most important for landslide reactivation. Some researchers also found that the number of antecedent days is related to the depth of the potential failure surface and larger windows of antecedent precipitation periods have to be considered for the deeper landslides (Van Asch et al. 1999, Terlien 1998). However, the role of short term events should not be ignored, especially in catchments where runoff reflects the short-term hydrological behaviour of the basin, particularly during extreme events.

Although the analysis of rainfall indicated the importance of antecedent conditions in reactivation of the Grohovo landslide as is the case with the initiation of landslides of similar geological setting in Croatia (Dugonjic and Arbanas 2012), because of the lack of data it is difficult to establish an empirical threshold and instead, a physically based rainfall threshold should be determined.
Address for correspondence:

Author’s Name: Maja Oštrić
Institution: Croatian Waters
Address: Đure Šporera 3, 51 000 Rijeka, Croatia
Phone: +38551666457
E-mail: maja.ostric@voda.hr
Disaster Mitigation of Floods and Debris Flow at Rijeka Region through Croatian-Japanese Collaboration

Nevenka Ožanić, Ivana Sušanj, Elvis Žic, Nino Krgravica, Igor Ružić, Nevena Dragičević, Goran Volf, Barbara Karleuša
Faculty of Civil Engineering, University of Rijeka, Rijeka, Croatia

This paper presents the objectives, activities and research results as outcomes from the bilateral Croatian – Japanese project „Risk Identification and Land-Use Planning for Disaster Mitigation of Landslides and Floods“, with the accent on the Faculty of Civil Engineering University of Rijeka activities within mud flow and flash flood working group (Working group 2 – WG2).

The Project „Risk Identification and Land-Use Planning for Disaster Mitigation of Landslides and Floods in Croatia“ was launched in 2008. when this project was elected as one of the projects in Science and Technology Research Partnership for Sustainable Development, SATREP funded by Japan Agency for Science and Technology - JST and Japan International Cooperation Agency - JICA. The Project is worth about 4 mill. US$ with duration of 5 years, and it involves about 20 researchers from Japan and 20 from the Croatia. Project leader from the Japanese side is Prof. Hideaki Marui - University of Niigata, a leader of the Croatian side is Prof. Nevenka Ožanić - University of Rijeka. One of the main goals of the project is hazard analysis and development of guidelines for the application of the project results in the spatial planning system. Project activities are carried out in the pilot areas which are located near Rijeka, Split and Zagreb.

The main activities of the research groups involved in the Croatian–Japanese joint research project on „Risk Identification and Land-Use Planning for Disaster Mitigation of Landslides and Floods in Croatia“ include investigations of recent landslides using landslide monitoring, the establishment and development of early warning systems for landslides, flash-flood and debris-flow simulation models, development of early warning systems adapted to hydrological and geological conditions in Croatia and the definition of hazard zones using a methodology for assessing susceptibility and hazards based on local geological and landslide conditions. The final objective of the joint research is the development of risk mitigation measures that can be instituted through urban planning. Dissemination and use of the results should ensure significant benefits for the local and regional communities that are directly and indirectly threatened by landslides, flash-floods and with debris-flow.

At the Working Group II (WG2), activities were conducted by systematic observations of meteorological and hydrological parameters in the planed catchment areas and river basin (rivers, flash floods and torrential areas) in real time, numerical and hydrological analysis of the measured parameters, and preparing simulation models of floods, mud flows and flow to the areas analysed for the purpose of making an early warning system for these phenomena, all adapted to the hydrological and geological conditions in Croatia. Necessary measuring and research equipment, software programs, systems and equipment for meteorological and hydrological observations for the most part were donate from the Government of Japan for the analysis of selected research areas in the vicinity of Rijeka. Some equipment were provided by the Faculty of Civil Engineering, University of Rijeka.

The Working Group II (WG2) has chosen three pilot areas are different in hydrological and geological characteristics, but partly also by the possible consequences: Rječina river catchment area - downstream profile near landslide Grohovo, catchment area of Dubravčina river and Mošćenička Draga near Opatija. Flood waters from these pilot areas can significantly affect the development of the area in which they are located. In fact, the flood waters of the river Rječina, river Dubravčina and debris flow of Mošćenička Draga can cause (and in history they are) significant damage to downstream urban areas (Rijeka, Crikvenica and Mošćenička Draga), and pose a high risk of possible future occurrence. Hydro analysis on these pilot areas of research will be conducted based on the results of an integrated monitoring system in real time. The establishment of early warning system will enable the safe operation of existing urban areas and their further development.

The benefits of the project are multifaceted because the results of research will contribute to the mitigation of natural disasters in Croatia. With these results are realized and other uses, such as better collaboration of scientists, experts and local communities. Involving and informing the public through the various stages of the project through public presentations and media, as well as in direct contact, turned out as extremely important and useful in collecting data and in implementation of the obtained solutions. In the integral paper will be given a detailed overview of research results for each of the pilot areas covered by these projects within WG2.
Acknowledgements

Conducted research shown in this paper was done at Faculty of Civil Engineering, University of Rijeka, Croatia. The research for this paper was conducted within the bilateral international Croatian-Japanese project “Risk identification and Land-Use Planning for Disaster Mitigation of Landslides and Floods in Croatia”, as well as a part of scientific project “Hydrology of Sensitive Water Resources in Karst” (114-0982709-2549) financed by Ministry of Science, Education and Sports of the Republic of Croatia.

References


Address for correspondence:
Author’s Name: Nevenka Ožanić
Institution: Faculty of Civil Engineering, University of Rijeka
Address: Radmile Matejčić 3, 51000 Rijeka, Croatia
Phone: +385 1 51 265 940
E-mail: nozanic@uniri.hr
Relationship between atmospheric conditions and groundwater level on Grohovo landslide

Goran Volf, Elvis Žic, Nevenka Ožanić
Faculty of Civil Engineering, University of Rijeka, Rijeka, Croatia

Grohovo landslide situated on the north-eastern slope of the Rječina valley is the largest active landslide along the Croatian part of the northern Adriatic coast. To contribute to understanding the effect of atmospheric conditions on groundwater level fluctuations on Grohovo landslide a machine learning tool for induction of models in form of set of rules was applied on a data set comprising daily atmospheric and groundwater level data measured in 2012. Atmospheric data comprise average daily air temperature, humidity, wind speed, pressure, total evapotranspiration, precipitations and sum of 5, 10, 15, 20, 25, 30, 35, 40 and 45 day precipitations. For the experiment atmospheric data were used as independent variables from which target variable; groundwater level is modelled.

Rule-based regression models for numeric prediction are interpreted as a set of if-then rules where each rule is associated with a multivariate linear model. A rule indicates that, whenever a case satisfies all the conditions, the linear model is appropriate for predicting the value of the target attribute. The algorithms for rule induction mostly represent different variations of the M5 algorithm. The algorithm implemented in a software package Cubist was applied for modelling, in which the basic M5 algorithm was enhanced by combining the model-based and instance-based learning.

The model describing groundwater level fluctuations consist of ten rules and have very high correlation coefficient of 0.99. Results of measured and modelled data of groundwater level are presented on Fig. 1. Of all atmospheric parameters (independent variables) presented above the model mostly used for rule induction 45 day precipitations (53%), air temperature (52%) and 35 day precipitations (33%). In equations which describes target variable are mostly used 45 day precipitations (82%), 10 day precipitations (77%), air temperature (74%), 20 day precipitation (72%) and 35 day precipitation (55%).

From the given model it can be concluded that the most influence on groundwater level fluctuations have sum of daily precipitations and air temperature.

Fig. 1 Measured and modelled groundwater level data on piezometer P1

Address for correspondence:
Author’s Name: Goran Volf
Institution: Faculty of Civil Engineering, University of Rijeka
Address: Radmile Matejčić 3, 51000 Rijeka, Croatia
Phone: +385 1 51 265 932
E-mail: goran.volf@gradri.uniri.hr
Applicability analysis of erosion assessment methods based on defined criteria and available data

Nevena Dragičević(1), Duncan Whyatt(2), Barbara Karleuša(1), Nevenka Ožanić(1), Gemma Davies(2),

(1) Faculty of Civil Engineering, University of Rijeka, Rijeka, Croatia
(2) Lancaster Environment Centre, University of Lancaster, Lancaster, United Kingdom

In recent decades there has been a significant development of erosion assessment methods that simultaneously followed the development of computer technologies, as well as Geographic Information Systems (GIS) and Satellite Imagery, thus enabling more detailed information’s about topography, land use and vegetation cover, as well as broaden the possibilities for the application of more demanding erosion analysis.

There are several papers that deal with the application of various erosion assessment methods depending on the needed scale [1,2,3] (from global to catchment size), erosion type (gully, rill, bank, sheet) [3] and their assessments by criteria such as prediction accuracy, erosion processes, needed data and calibration [8].

Within this paper twenty-two different erosion assessment methods are analysed and compared with the purpose to define the relevance of each used criterion, better understanding of erosion processes, as well as to give future guidance for simplifying the procedure of choosing the appropriate method based on available data and relevant criteria. Methods encompassed with this analysis are Pacific Southwest Inter-Agency Committee (PSIAC), PSIAC adapted version, The vegetation-surface material-drainage density (VSD), Erosion Potential Method–Gavriloğlu (EPM), Factorial Scouring Model (FSM), Erosion hazard units (EHU), Soil Loss Estimation Model for Southern Africa (SLEMSA), CORINE erosion risk maps, Coleman and Scatena scoring model (CSSM), Fleming and Kadhim scoring model (FKSM), Wallingford scoring model (WSM), Universal Soil Loss Equation (USLE), Revised Universal Soil Loss Equation (RUSLE), RIVM Model, INRA Model, SCALES Model, Fournier, Water Erosion Prediction Model (WEPP), Soil and Water Assessment Tool (SWAT), Morgan-Morgan-Finney (MMF), Annualized Agricultural Non-Point Source Pollution (AGNPS) and Modified Universal Soil Loss Equation (MUSLE) [1,2,3,4,5,6,7,8,9,10,11].

There are fifty one used criteria within these methods that can be divided into ten main groups (soil, climate and precipitation, runoff, water network, topography, vegetation cover and land use, upland erosion, channel erosion and sediment transport, catchment characteristics and other). Ten most used criteria are precipitation, erosivity or rain intensity (72.73%), slope angle (72.73%), soil erodibility (68.18%), percentage of vegetation cover (40.91%), cover type (36.36%), runoff (31.82%), agricultural practice (31.82%), soil type (22.73%), slope length (22.73%), agricultural land (13.64%), all of which represent only five out of ten criteria groups (topography, climate and precipitation, soil, vegetation cover and land use, runoff).

By group statistic, where at least one of the group criteria is used in each method, vegetation cover and land use, can be considered the most significant one, with the use percentage of 95.45%, followed both by soil and topography groups with 86.36% and climate and precipitation with 81.82%. There is a minimum gap of 45% between the use of first four group criteria and the rest of the groups (eg. Runoff is fifth by 36.36%).

Taking into consideration conducted analysis and complementing it with the knowledge about erosion processes obtained from the literature, significance of the criteria can be concluded. Since, rainfall is considered the most important detaching agent and erodibility and type of the soil define susceptibility of the soil to detachment, these criteria can be considered the most important ones. When detached, soil is transported further by erosion agents (eg. running water) during which topography (eg. slope angle) has a major impact upon the distance, speed and pathways for the runoff and sediment transport, imposing this criteria as relevant when making methodology selection. Agricultural practice, the growth cycle of the plants, % of vegetation cover, the constructions sites, excavation of mineral resources, form vegetation cover and land use group. If not managed properly, this criteria can contribute to the increase of erosion detached sediment, and therefore needs to be taken into consideration [12,13,14].

The first step to predict erosion and its severity on the area of interest is choosing the methodology to apply. The restrictions of scale applicability of a method, and type of erosion the method deals with, has already been covered within literature [1,2,3]. The accessibility of a data is often the crucial factor in the process of method selection. For this reason it is necessary to take into consideration all four criteria (scale, erosion type, criteria significance and available data) in order to make the best method selection.
Today, continuous development of technology has enabled new and more detailed spatially variant data, as well as provided various different sources for the same data category (such as landcover). That also brought the challenges for appropriate data selection within various sources, where each decision made will have its own impact on the final result.

The proposed methodology has been applied on Dubraca catchment area in Croatia by which the choice of applicable methods was narrowed to: Gavrilovic, FKS and Fournier method. The Gavrilovic method has been developed for catchments with karstic terrain and torrential rivers, as well as taking into consideration the previously mentioned significant criteria, all of which are available and correspond to the Dubraca catchment. The challenge was to choose one over several available data of the same type but different source, or combining them into one secondary data with the help of GIS (eg. vegetation cover and land use). Also some elements included in the method were not available for previous researches in such detail and spatial variance (eg. drainage density) and some were available as limited number of point sources (eg. precipitation) thus making additional challenge in transferring them to spatially variant data.

Acknowledgements

Conducted research shown in this paper was done at Lancaster Environment Centre, University of Lancaster, United Kingdom and financially supported by The British Scholarship Trust. The research for this paper was conducted within the bilateral international Croatian-Japanese project “Risk identification and Land-Use Planning for Disaster Mitigation of Landslides and Floods in Croatia”, as well as a part of scientific project “Hydrology of Sensitive Water Resources in Karst” (114-0982709-2549) financed by Ministry of Science, Education and Sports of the Republic of Croatia.

References


Address for correspondence:

Author’s Name: Nevena Dragicevic
Institution: Faculty of Civil Engineering, University of Rijeka
Address: Radmile Matejčić 3, 51000 Rijeka, Croatia
Phone: +385 1 51 265 900
E-mail: nevena.dragicevic@umir.hr
Application of ‘Structure-from-Motion’ photogrammetry for erosion processes monitoring, Mošćenička Draga example

Igor Ružić(1), Ivan Marović(1), Martina Vivoda(1), Sanja Dugonjić Jovančević(1), Duje Kalajžić(2), Čedomir Benac(1), Nevenka Ožanić(1)

(1) Faculty of Civil Engineering, University of Rijeka, Rijeka, Croatia
(2) University of Rijeka, IT Services, Rijeka, Croatia

In last decades we all witnessed a technological revolution in terrestrial scanning, ground surveying, data analysis, and creating more quality of digital elevation models (DEMs). High-resolution topographic surveying is traditionally associated with high capital and logistic costs. Low-cost photogrammetric method named “Structure-form-Motion” (SfM) is ideally suited for low-budget research and application in remote areas (James, 2012; Westoby, 2013). SfM method was developed in the 1990s and operates under the same basic tenets as stereoscopic photogrammetry, namely that 3D structure can be resolved from a series of overlapping, offset images.

The aim of this paper is to present abilities of SfM photogrammetry and its application in geomorphological terrain analysis. The focus is to show 3D point clouds and digital elevation model delivered from an image sets. Images were acquired by low-cost digital camera on terrain, and later were transformed into point cloud using Autodesk software ReCap. 3D point cloud model was geo-referenced and processed with a Matlab algorithm. As for each terrain photo-series the geo-referenced DEM was made, the changes were compared on the basis of two 3D point clouds.

Investigated sight is located in Mošćenička Draga torrential flow catchment, approx. 2km NE from Mošćenička Draga settlement, 15 km SW from Rijeka. Sight is app. 40 m wide and 40 m height. Slopes are very steep to vertical and formed in talus breccias. This sediment type has less resistance from erosion. The catchment area of Mošćenička Draga is one of research locations in Croatian-Japanese project “Risk identification and land-use planning for disaster mitigation of landslides and floods in Croatia”.

Fig. 1 shows investigated sight, its 3D point cloud delivered from a SfM photogrammetry and three sight profiles.

Fig. 1. Left: Talus breccia sight, middle: 3d point cloud, right: profiles plot (m), 26/11/2013

Images for SfM reconstruction were taken on several occasions between 2011 and 2013. To assess the quality of the SfM 3D point cloud, results from the survey delivered in November 2013 were compared with RTK-GPS acquired points. SfM point cloud was geo-referenced using linear transformation based on clearly visible Ground Control Points (GCP) relative (image) and absolute coordinates. GCP were marked before image acquisition, and their coordinates were measured with RTK-GPS. Inside interpolated area (area inside GCP) differences between SfM 3D point cloud and RTK-GPS acquired points were less than 3 cm, while extrapolated points (area outside GCP) had differences up to 10 cm. Average SfM 3D point cloud density about 2000 points per square meter provides sufficient detail of the feature's surface. We used standard ReCap 3D model mesh size. It is possible to use even higher mesh size if higher density is required.

The presented 3D model delivered from an image set has adequate quality for valuable use in visualizing and quantifying slopes morphological change. Presented technique is convenient for frequent acquisition of high-resolution DEM at a fraction of the time and cost of alternative approaches. One of the application of Structure-from-Motion photogrammetry method is monitoring of landslide movements. So method utilization in real-time landslide monitoring is one of the future plans.
References


Address for correspondence:
Author’s Name: Igor Ružić
Institution: Faculty of Civil Engineering, University of Rijeka
Address: Radmile Matejčić 3, 51000 Rijeka, Croatia
Phone: +385 1 51 265 942
E-mail: igor.ruzic@uniri.hr
Performance analysis of X-band radar rainfall measurements in the Kvarner region

Nino Krvavica(1), Igor Ružić(1), Yosuke Yamashiki(2), Nevenka Ožanić(1)

(1) Faculty of Civil Engineering, University of Rijeka, Rijeka, Croatia
(2) Graduate School of Advanced Integrated Studies in Human Survivability, Kyoto University, Japan

Accurate rainfall measurement – its intensity and spatial distribution – is crucial for both hydrological research and development of early warning system for floods and landslides. On a complex and mountain terrain even a large number of rain gauges are not enough to accurately measure spatial rainfall variability over wide areas such as river catchments. Weather radar offers a way to measure precipitation with both high spatial and temporal resolution. But before radar measurements can be used for hydrological application it is necessary to analyse the data by comparing it to the rain gauge data in order to assess its accuracy and if necessary, choose appropriate calibration methods.

Radar used in this study is Mini X-band Dual Polarimetric Weather Radar, manufactured by Furuno Electric Co., LTD. This X-band radar was donated by the JICA (Japan International Cooperation Agency) for scientific research on Croatian-Japanese bilateral project “Risk Identification and Land-use Planning for Disaster Mitigation of Landslides and Floods in Croatia”. It was installed on November 2012 on the roof of the Faculty of Civil Engineering building located at the main campus of the University of Rijeka in Croatia. The radar has a range resolution of 96 m, and temporal resolution of 60 sec to cover a full 360° circle. Although this is a dual polarimetric radar, it is still in development and during the period from November 2012 to July 2013 it operated as a Doppler radar, with a single horizontal polarization.

Collected radar data from six month period was compared to two rain gauges; one located at Valići Dam, near the Grohovo landslide area, at the distance of 4.9 km from the radar site, and the second one located at Kozala, 2.1 km from the radar site. Those two rain gauges were chosen because of their proximity to the radar site, in order to eliminate the influence of attenuation as much as possible. The rain gauges are standard tipping-bucket gauges with a volume resolution of 0.2 mm and a 10 minute and 5 minute recording interval, respectively.

In the period from November 2012 to May 2013, 25 rain events satisfied the following criteria – either one of the two rain gauges have recorded at least 10 mm of rain in a 24 hour period. In some of those cases one or the other rain gauge did not work properly and in others snow precipitation was observed. That data was excluded from the analysis, which left a total of 18 rain events appropriate for radar - rain gauge comparison.

Rainfall cannot be directly measured by weather radar, so an empirical Z-R relationship $Z = A \times R^b$ (where $Z$ is radar reflectivity and $R$ is rainfall intensity) is generally used to assess the intensity of rainfall. By analysing a series of measured radar reflectivity and measured rainfall from both rain gauges a new Z-R relationship ($Z = 184 R^{1.6}$) was found that showed better statistical indicators than the generally used Marshall equation ($Z = 200 R^{1.5}$).

Radar calibration is assessed by comparing one hour rain intensity calculated from the measured radar reflectivity and one hour rainfall measurements from both rain gauges, during those 18 rain events. Correlation coefficient and several statistical indicators (root mean square error, mean absolute error and mean bias error) where used in the analysis. The results showed strong or very strong correlation between radar and rain gauge data in majority of the rain events $r > 0.7$ (26 out of 36 cases), but for some rain events the correlation was very weak $r < 0.2$ (3 out of 36 cases). Average root mean square error was around 1.2 and mean absolute error was around 0.8, average mean bias error was positive which suggested a tendency for radar underestimation. In general, radar showed stronger correlation and smaller errors in comparison to Grohovo, than to Kozala meteorological station, which is a bit unexpected because Kozala station is closer to the radar site and thus less prone to attenuation. Additional measurements are needed to assess radar performance, especially during extreme, high intensity rain events.

Address for correspondence:

Author's Name: Nino Krvavica
Institution: Faculty of Civil Engineering, University of Rijeka
Address: Radmile Matejić, 3, 51000 Rijeka, Croatia
Phone: +385 1 51265998
E-mail: nino.krvavica@gradri.uniri.hr
Debris flows generate important yearly human and property losses. Its analysis is important to assess the risk and to delimitate vulnerable areas where mitigation measures are required. Debris flows are a type of mass wasting processes. Mass movement processes can be categorized following some parameters such as the release mechanism, the sort of material, the sediment composition, the proportion of the solid phase, the velocity, the time of the event, the slope of the movement plane, the material behavior and the physical processes during the mass movement.

Predicting both the runout distance and the velocity through mathematical modeling of the propagation can avoid important losses. Moreover data from modeling can be used as input in risk studies, where hazardous areas are defined and appropriate protective measures are designed.

In the last decades, modeling of propagation stage has been largely carried out in the framework of the continuum mechanics, and a number of new and sophisticated numerical models are developed. Most of the available approaches handle the heterogeneous and multiphase moving mass as a single phase continuum. The Smoothed particle hydrodynamics model (SPH model) described here after consists on considering two phases, a granular skeleton with voids filled with either water or debris/mud. If the shear resistance of the fluid phase can be neglected, the stress tensor in the mixture can be decomposed into a "pore pressure" and an effective stress, and the mechanical behavior of the mixture can be described by a system of differential equations governing the dynamics of each of the phases. Once the required initial and boundary conditions are provided, the spatial and temporal integration of the system of differential equations can be carried out with numerical methods.

In the SPH method, the state of a system is represented by a set of particles, which possess individual material properties and move according to the governing conservation equations. SPH method, as a meshfree, Lagrangian, particle method, has its particular characteristics. The key idea of the meshfree methods is to provide accurate and stable numerical solutions for integral equations or PDEs with all kinds of possible boundary conditions with a set of arbitrarily distributed nodes (or particles) without using any mesh that provides the connectivity of these nodes or particles. SPH method has some special advantages over the traditional grid-based numerical methods, the most significant one among which is the adaptive nature of the SPH method. This adaptability of SPH is achieved at the very early stage of the field variable approximation that is performed at each time step based on a current local set of arbitrarily distributed particles.

The SPH depth integrated model is a 2D model able to predict runout distance, flow velocity, deposition pattern and final volume of debris flows. It is based on a mathematical model, on rheological models and on a numerical model. The basis of the mathematical model is a coupled depth integrated model coming from a velocity-pressure version of Biot-Zienkiewicz equations. The rheological models correspond to constitutive equations. The SPH depth integrated model is a calibration-based model, which means that the appropriate rheological parameters must be constrained by back analysis of previous real debris flows.

In this paper are described the main characteristics of debris flow processes and point out the more relevant parameters and magnitudes describing debris flow. The paper also gives the main equations on which is based the SPH depth integrated model applied for Grohovo landslide. In this paper two erosion laws are presented, the Hungr erosion law and the Egashira erosion law. On the end of the paper was given a brief description of the SPH code, and some conclusions of this case study and the possible future research lines.

Address for correspondence:

Author’s Name: Elvis Žic
Institution: Faculty of Civil Engineering, University of Rijeka
Address: Radmile Matejčić 3, 51000 Rijeka, Croatia
Phone: +385 1 51 265 933
E-mail: elvis.zic@uniri.hr
Physical modelling of debris flow movement - laboratory research

Elvis Žić(1), Yosuke Yamashiki(2), Shota Kurokawa(2), Shigeo Fujiki(2), Nevenka Ožanić(1)

(1) Faculty of Civil Engineering, University of Rijeka, Rijeka, Croatia
(2) University of Kyoto, Disaster Prevention Research Institute, Kyoto, Japan

A debris flow is a mixture of water, poorly sorted sediment and other debris, typically flowing rapidly, with one or more surges and a coarse-grained front. Both solid and fluid forces strongly influence the motion, distinguishing debris flows from related phenomena such as rock avalanches and sediment-laden floods. Debris flows in the more restrictive sense have a significant amount of coarse particles particularly near the front region.

With respect to the hazard assessment of torrent catchments, it is important to determine whether debris flows are likely to occur or not. The basic requirements for the occurrence of debris flows are steep slopes, sufficient volumes of debris material relatively easy to mobilize, and sufficient water to trigger the flow. Debris flow hazard recognition is a very important step and may be based on the geomorphic evidence, aerial photographs, satellite imagery, geomorphology and topography, historical accounts and records or development of physical models in the laboratory.

Physical modelling consists of representing phenomena at a small scale in similarity with real phenomena. For debris-flows, this requires to use specific model fluids whose adequate composition remains an important scientific issue. Observations of laboratory tests using model scale flumes can aid our understanding of the mechanics of debris flows – and hence, help us to assess the spatial component of risk, given a particular geometry and set of materials.

The main aim of this study is to understand the characteristics movements of stony debris flow to predict the debris flow disasters routing through laboratory experiments. In that aim, this study focuses on capturing process of debris flow particle routing segregation for channel slope angle of 25°, debris flow deposition on the deposition board, erosion processes at the downstream and upstream of the experimental channel.

In order to understand the characteristics of debris flow routing mechanism and the deposition behavior, it is necessary to set up a debris flow experimental physical model of study. Experimental setup of the debris flow physical model was carried out at the Ujigawa Open Laboratory, Kyoto University. The model consists of three main parts which are rectangular flume, deposition board and water intake tank. The deposition board slope can varied from 0° to 7°.

Three cases of laboratory experiments are conducted in this paper with the same slope angle of 25°. Experiments were conducted separately but the water discharge was set as same for each case. The debris was placed 3.5m from the bottom of the rectangular flume. The debris was well mixed up between small, medium and big materials. The mixed particles were set on the bed of the experimental flume in the beginning and transported by fluids afterwards. A constant discharge (3.0 l/s) is supplied within 4s. During water supply, high speed video camera (HSVC) will recorded the image of particle routing. The HSVC have been placed at two locations, one place is near downstream and another place is near the upstream of the rectangular flume. Moreover, two video cameras were set at different locations to record continuous and simultaneous process of debris flow deposition process.

Three different sizes of materials are used in the physical model. The materials mean sizes were 10mm, 5mm and 2.5mm respectively. The materials had been used have a same unit weight which are 2.7gcm⁻³. For single run the total weight of each material is approximately 10kg.

In this study, the data collection can be separate to three parts which are sampling of the materials, observation of the material depositions and image capture from HSVC and camcorder. The objective of the sampling processes is to get the percentage of materials at different node at different height. This process involved four steps. First step was materials collection at certain node that been identified. After that, materials at different height had been packed and marked. Then each packed had to be dried at 105°C for 24 hours. Reason for doing this is to make sure that the materials is really dried to get a good result. The last step just after drying process was by take a weight of each sample.

The main goals of this study are to understand the particle characteristics, particle distribution and the physical data of the deposition materials. Observation of the deposition processes included (1) measuring deposit shape and thickness distribution, (2) mapping surface structure, (3) deposition contour sketch and (4) reviewing video and still photographs of the stages of the debris deposition formation. These four processes had to be done and repeated more than once time to get the accurate results.

From the results of HSVC analysis of particle routing segregation of debris flow the results show that the big particles gather at the top layer in flow and the speeds of big particles are higher compared to those small and medium
particles. The small particles concentrated near the bottom of the flume channel with slower velocity. As a result, big particles are arrived and gathered near the entranced of the deposition board.

The shape of debris flow depositions have influenced by the characteristics of big, medium and small particles just after arrived at the deposition section. When big particles are accumulated and concentrated first at the tip of the flow layers then they afterwards affect strongly on accumulation of small and medium particles. According to studies on model, the position of big particles which accumulate first affects the shape and the direction of following debris flow deposition.

The debris materials composition at “fan” deposition area clearly showed the characteristics of the particle segregation. Larger particles transported with higher velocity deposit at the middle of the debris-flow fan at lower layer that influenced the smaller particle deposition patterns spreading wider area. The prediction of larger particle movement is essential to comprehend the debris flow fan formation.

Address for correspondence:
Author’s Name: Elvis Žic
Institution: Faculty of Civil Engineering, University of Rijeka
Address: Radmile Matejčić, 3, 51000 Rijeka, Croatia
Phone: +385 1 51 265 933
E-mail: elvis.zic@uniri.hr
Analysis of the rainfall impact on variation of the underground water level on the Slani potok catchment area

Ivana Sušanj, Nevenka Ožanić
Faculty of Civil Engineering, University of Rijeka, Rijeka, Croatia

In this paper, preliminary analysis of the rainfall impact on variation of the underground water level as a part of hydrological analysis in the order of the rainfall-runoff model development will be presented. For the purpose of analysis, Slani potok catchment area is chosen. Slani potok is torrential Dubračina river tributary which is a part of the bilateral Croatian-Japanese project “Risk Identification and Land-Use Planning for Disaster Mitigation of Landslides and Floods in Croatia” and was chosen for its historical significance of potential hazard development. The first step in hazard mitigation and prevention strategy is establishment of early warning system for this area that is going to be applied from results of the hydrological rainfall – runoff model.

Slani potok catchment area may be considered as an example of combined erosion. Excessive surface erosion occurs on the area of 600 m in length and 250 m in width. Side effects around the erosion centre are landslides, which are the results of weathering of the flysh rock mass. The size of this affected area is about 3 km² and the surrounding settlements Belgrad, Baretići, Grižane and Kamenjak are at risk as well as the surrounding roads.

The basin of Slani potok has area of approximately 2 km², and its altitude extends from 50 m a.s.l. to 700 m a.s.l. The lower part of the catchment area (0.9 km²), is formed in flysh sediments (mainly silt stone) that are partly covered with alluvial materials, represent the majority of runoff. The upper part of catchment area is a karstic plateau from which the runoff is insignificant. In the karst and flysh contact zone is more overflow springs that make the majority of water balance in the dry season (Fig. 1).

For the development of the hydrological model it is very important to understand runoff process on research area, which is mainly consisting of direct surface and base underground runoff. Direct runoff is a part of the total runoff on catchment area that occurs quickly after rainfall event and the capacity of surface ground infiltration is exceeded while the base runoff can be determinate as underground runoff that occurs slowly and long after rainfall event.

The aim and objective or this paper is determination of rainfall impact on the underground water level by infiltration, and for this purpose monitoring equipment was installed. Rainfall is measured by meteorological station Vantage Pro 2 manufactured by Davis Instruments Corporation. Underground water level is monitored by continuous measuring of water levels by use of the pressure sensors Mini Divers manufactured by Schlumberg Water Services that are installed in three piezometres. Piezometres were bored on the karst and alluvial covered flysh contact area (Figure 1.). Flysh is mainly impermeable material and underground flow of water can occur only in cover layer of alluvial material which thickness is on that area approximately ten meters.

Fig. 1 Slani potok catchment area on geological map with position of installed equipment
By comparison of rainfall and underground water level data that was made by program package MATLAB R2012a developed by MathWorks, it is identified that four big rainfall events (from May to October in 2013 year) had influence on the change of underground water levels and those events were analyzed in detail (Fig. 2). As a result of analysis the reaction time of underground water levels from the start of rain event is going to be presented as well as the amount of crucial rainfall that is required for the occurrence of underground water levels changes. Also correlation coefficient between reaction time of underground water levels from the start of rainfall event and amount of rainfall that triggers the change of underground water level will be obtained.

![Fig. 2 Comparison of rainfall and underground water level data](image)

In the further hydrological analysis, comparison of rainfall data, underground water levels and river water levels after big rain events will be done in the order to separate the direct (surface), base (underground) runoff and capacity of infiltration by which main parameters for development of rainfall – runoff model will be determined.

**Address for correspondence:**

Author’s Name: Ivana Sušanj  
Institution: Faculty of Civil Engineering, University of Rijeka  
Address: Radmile Matejčić 3, 51000 Rijeka, Croatia  
Phone: +385 1 51 265 942  
E-mail: ivana.susanj@gradri.hr
Explicit vs. Implicit Time Integration of Saint-Venant Equations for Flood Wave Propagation

Vanja Travaš, Nino Krvavica
Faculty of Civil Engineering, University of Rijeka, Rijeka, Croatia

The main motivation for this paper arises from the intention to develop a one-dimensional numerical framework which should approximately predict the geometrical and mechanical features, e.g. volume and momentum, of rigid fragments transported by a flow along an open channel. For this purpose a one-dimensional phenomenological constitutive law will be used. Apart from initial and boundary condition for the water flow, appropriate initial and boundary conditions should also be specified for the flow of fragments. Those numerical and mechanical considerations are still in development. However, since the transport process will be mainly affected by the velocity of the flow and the water depth, spatial distribution of both variables should be obtained in advance.

Although it is not strictly required, hypothetical flood wave propagation along a prismatic open channel is considered herein. To obtain an estimation of velocity and water depth distribution along the channel, the Saint-Venant system of differential equation (continuity and momentum equations) is integrated by two different numerical methods. From the computational point of view, the attractive explicit time integration technique, based on the method of characteristics, was used to obtain a numerical approximation for velocity and depth. This numerical algorithm was implemented in MathCAD 15. On the other hand, the evidently more computationally demanded technique, the implicit time integration, based on the finite difference Preissmann scheme, was used to obtain a system of algebraic equations that was afterward solved in MATLAB by Newton-Raphson method. Comparative analysis between the two numerical methods was conducted to evidence the efficiency of the explicit time integration compared to the implicit one. Namely, although the Preissmann scheme allows the use of variable time and spatial steps, which make this method convenient for applications in routing of flood hydrographs in natural rivers, the explicit time integration gives an efficient and simple numerical procedure that can be extended to include different flow environments such as debris flow.

The comparative study between the considered numerical methods is performed for flood wave propagation along the prismatic channel with similar geometry to the Rječina River. Values of depth and flow rate at the beginning of simulation are specified at all nodes along the channel as initial conditions. The boundary conditions were specified as water elevation at the upstream flow section and no-flux condition at the downstream section. As an output of the model, the dependency between the flow rate and the depth at the downstream section was retrieved. By comparing the results, a significant disagreement in both depth and flow rate at the downstream boundary was evidenced between the two methods. The explicit method showed smaller depth and flow rate of the flood wave peaks at the downstream boundary than the implicit method. Arrival times of flood wave peaks at the downstream end of the spatial domain in those two methods also differed significantly. The explicit method showed longer arrival times than the implicit method.

Although, explicit methods are computationally simpler and less demanding than the implicit methods, when modeling flood wave propagation through a relatively longer channel, selection of the appropriate numerical scheme should be considered with great care if precision and accuracy is important.

Address for correspondence:
Author’s Name: Vanja Travaš
Institution: Faculty of Civil Engineering, University of Rijeka
Address: Radmile Matejčić, 3, 51000 Rijeka, Croatia
Phone: +385 1 51 265 998
E-mail: vanja.travas@gradri.hr
WORKING GROUP 3: HAZARD MAPPING
Awareness of Flood Risk in different generations in Zagreb

Naoko Kimura(1), Yosuke Yamashiki(1), Ivica Kisić(2)

(1) Kyoto University, Graduate School of Advanced Integrated Studies in Human Survivability, Japan
(2) University of Zagreb, Faculty of Agriculture, Zagreb, Croatia

This study aims to make suggestion for future awareness-raising towards disasters, especially focusing on floods, in Zagreb through analysis of social survey results and awareness-raising materials from public organizations. The study is constructed with triangulation of material and document analysis, social survey (questionnaire), and semi-structured interview to senior citizens who experienced a huge flood happened in Zagreb in 1964.

UNICEF and UNISDR have given overview and descriptions on educational actions and activities for disaster risk reduction for children in Croatia as a brief country profile in its report, and some activities have been ongoing with an approach art painting event for young children, while disaster related issues are taught in a segment of academic subjects, especially geography and pointed out both lack of teaching skills regarding disasters and tendency of overload in academic subject curricula in formal school setting in upper primary and secondary level. Public organizations such as National Protection and Rescue Directorate (NPRD) and Office for Emergency Management (OEM), municipality Government of Zagreb City, have published informative brochures related to actions to take in an emergency case. OEM’s effort of budge with QR-code for children is also unique so that they can access their brochure with mobile phone.

Social survey, questionnaire, was conducted to 96 students of in first grade of secondary school in January 2012, to university students and teaching staff, total 253, as well as to 20 senior citizens who experienced a huge flood in 1964 in November 2011. Semi-structure interview was also included to those senior citizens focusing on how they evacuated and their general memory about the flood. The results of the questionnaire showed a clear difference depending on generation, in particular in future flood in Zagreb. More than 70% teenagers think that there may be a flood to happen in Zagreb in 10 years whilst it was less than half among the respondents in their 60s or above. Regarding the preparation status, the generation of 40s and 50s showed rather higher rate in recognition of their preparation for flood at home regardless of their expectation on future flood, disaster experience, or fear to extreme weather. The result also showed that people in Zagreb do not have much experience of disaster at all and have no image of what it is like, especially children. Last but not least, there was also a gender gap in preparation recognition was observed, which preparation status is lower in female.

By and large, there have been good information sources related to evacuation in an emergency case for different types of disaster in Zagreb. The approaches by public organizations have become active and recognized by international organizations as well. In emergency assistance, there are three types of assistance, governments/public, community, and personal or individual. Experts in disaster risk reduction assert that the vector of information provision from government/public organization and that of acquiring information and learning from citizens/individual are to be met in a good balance. Taking the Japan-Croatia bilateral project into account, development of early warning system shall be a very good input and contribution for further enhancement of information provision from governmental side. This research concludes with a suggestion to boost up creating opportunities for citizens’ to learn what to do and how in a practical manner, which is not to scare them but to have them as catalysts for future generations within sustainable development.

**Keywords:**

disaster risks, flood, awareness, preparedness, citizens, Zagreb

**Address for correspondence:**

Author’s Name: Naoko Kimura
Institution: Graduate School of Advanced Integrated Studies in Human Survivability, Kyoto University
Address: Kyoto Technoscience Center, 14 Yoshida-Kawaracho, Sakyo-ku, Room No.15
Phone: +81-(0)75-744-0411
E-mail: kimura.naoko.4v@kyoto-u.ac.jp
Hazard Mapping for WG4 Case Study

Snježana Knezić, Predrag Miščević, Martina Baučić, Ivo Andrić, Goran Vlastelica

University of Split, Faculty of civil engineering, architecture and geodesy, Split, Croatia

Split case study comprises areas exposed to both flash floods and rock-falls. Areas directly exposed to flash floods are mainly related to Cetina river watershed while areas endangered by rock-falls are two limited areas: town of Omis and area in the municipality of Duće. The paper shows a methodology for hazard assessment for both phenomena.

The hazard assessment for flash floods is based on the measured data and other spatial information and/or analysis provided by GIS. The methodology takes into account European Flood Directive. The criteria for the hazard of flood assessment are based on the available, collected and processed data. Use of satellite remote sensing data enables DEM analysis (topography, geomorphology, flow accumulation, land use and vegetation), whereas traditional collected data give information on hydrology, meteorology, geology, infrastructure, human settlements and historical record. A preliminary hazard map based on water depth has been evaluated for Sutina-Karakasica part of the watershed.

Since spatially distributed assessment of rock-fall hazard is a difficult due to high uncertainty and lack of exact mathematical methods for calculation of rock movements the main principle for the proposed methodology is based on GIS and results from more detail geodetic measurements such as Terrestrial laser scanning (TLS) or satellite remote sensing. The criteria for the hazard of rock fall assessment are mainly connected to geology, geomorphology and topography (slope angle, approximation of mass of the potential loose blocks, cracks distribution) and meteorological data (precipitation, temperature fluctuations). Traditional integrated development planning information such as structure of endangered base of rock fall slope (infrastructure, settlements and historical record) is another significant criterion. A preliminary hazard map based on abovementioned criteria has been developed.

Address for correspondence:

Author’s Name: Snježana Knezić
Institution: University of Split, Faculty of Civil Engineering, Architecture and Geodesy
Address: Matice hrvatske 15, 21000 Split, Croatia
Phone: +385 21 303 360
E-mail: snjezana.knezic@gradst.hr
Overview of Input Data for the Landslide Hazard Analysis in the Dubračina River Basin

Petra Domlija(1), Sanja Bernat(2), Ćedomir Benac(1), Snježana Mihalić Arbanas(2), Martin Zidarić(3)

(1) Faculty of Civil Engineering, University of Rijeka, Rijeka, Croatia
(2) Faculty of Mining, Geology and Petroleum Engineering, University of Zagreb, Croatia
(3) Geoprojekt d.d. Opatija, Rijeka, Croatia

Investigations of recent and past landslides in the Dubračina River Basin have been conducted in the aim to define hazard zones, using a methodology for assessing susceptibility and hazard based on local geological and geomorphological conditions. Activities necessary to provide planned landslide susceptibility assessment and hazard analysis include landslide mapping to generate a landslide inventory, followed by mapping of causal and triggering landslide factors (Mihalić and Arbanas, 2012). An overview of the input data required for landslide susceptibility and hazard assessment is given, of which some of the data are in a preliminary phase of preparation. Input data are subdivided into two main groups: landslide inventory map and landslide causal factors. Landslide causal factor encompass two subgroups of data: preparatory causal factors and triggering factors.

Almost all of the landslides are situated in the part of a valley being built of siliciclastic rock mass mostly covered by slope deposits. This paper presents preliminary landslide inventory map with data about locations of landslides identified by visual interpretation of LiDAR (Light Detection and Ranging) imagery supplemented by field reconnaissance mapping. The hillshade map was generated with an azimuth of 315° and the sun angle of 45° draped over a bare earth DEM. The slope map was created to characterize the degree of terrain slope and is classified by categories of the slope angles showing the areas of high slope angle in warmer (red, orange, yellow etc.) and areas of low slope angle in cooler (green) colours. Systematic landslide mapping was performed at the area of geomorphological unit of hills within the siliciclastic rock mass with total size of 10 km² (Bernat et al., in press). There are 53 identified landslides. Most of the landslides are clearly visible on LiDAR imagery and there are also landslides for which additional filed checking was necessary for identification.

The landslide causal factors present a collection of data that are expected to have an effect on the occurrence of landslides. For derivation of morphological causal factors there is available high precision Digital Elevation Model (DEM) of the investigated area which was derived from the airborne LiDAR data. Geological causal factor will be derived from large scale (1:5,000) geological map made by Croatian geological survey in 2007. According to genesis of the Dubračina River Basin, it is necessary to derive geomorphological unit map by combination of topographic and geological data. Geomorphological data are presented by the geomorphological map showing different landform units outlined regarding to lithological units, geomorphological features and hydrological conditions. One of the important causes of landslides are also phenomena of excessive erosion described in Aljinović et al. (2010). Erosion map is necessary to depict areas of bad-lands as well as areas where vegetation cover is progressively removing by planar erosion. The stream network and positions of springs are presented in the hydrological map. Land cover map presents different vegetation types distribution according to CORINE (Coordination of Information on the Environment) data base from 2006. Land use map presents types of the land use and also the spatial distribution of settlements, roads and structures. Large scale (1:5,000) road map was derived by digitizing roads from topographic map HOK (Croatian Basic Map) and it is important as landslide causal map because of high relative importance of roads (e.g., defective construction or maintenance of drainage system) to landslide activation.

The landslide triggering causal factors generally have more temporal than spatial importance. This type of data is referred to the rainfall and the earthquake records over sufficiently large time periods. The input data for derivation of rainfall distribution map are precipitation data from the 8 individual meteorological stations. On the basis of preliminary analysis it is known that daily cumulative precipitation is relevant as landslide triggering factor. Spatial distribution of mean annual rainfall amount can only be used as rough indicator of spatial variation of rainfalls quantities which is caused by changes of local relief at small distances. Seismological data are presented as the ground motion acceleration map based on the available national earthquake catalogue.

Comprehensive landslide hazard mapping and zonation in the Dubračina River Basin should encompass all the landslide phenomena, including rock fall phenomena in the limestone wall geomorphological unit as well as soil/debris flow phenomena in the hilly area of siliciclastic rock mass. There are also geomorphological units at the investigated area in which development of landslides are not possible (alluvial plane, proluvium). Spatial distributions of
geomorphological units is important as a first step in the landslide hazard analysis to define type of geomorphological processes, i.e., landslide phenomena (slide, rock fall, flow) and related erosional phenomena (linear and planar). Landslide frequencies, as indicator of landslide hazard, can only be expressed for particular landslide type per relevant geomorphological unit.

References


Address for correspondence:

Author’s Name: Petra Domlija  
Institution: Faculty of Civil Engineering, University of Rijeka  
Address: Radmile Matejčić.3, 51000 Rijeka, Croatia  
Phone: +385 1 51 265 959  
E-mail: petra.domlija@gradri.uniri.hr
Landslides Triggered in the City of Zagreb in the Winter of 2013

Sanja Bernat, Snježana Mihalić Arbanas, Martin Krkač
Faculty of Mining, Geology and Petroleum Engineering, University of Zagreb, Croatia

The winter period of 2013 in the City of Zagreb, capital of the Republic of Croatia, had extreme weather conditions that caused (re)activation of 65 landslides in the pilot area of WG3 of the Croatian-Japanese SATREPS FY2008 project. In the same period in the continental part of Croatia, Croatian National Protection and Rescue Directorate (DUZS) recorded more than 900 activated landslides (Bernat et al., in press). The highest number of reported landslide events is in the NW Croatian counties.

The pilot area of WG3 encompasses the hilly area of the southern foothills of the Medvednica Mt. in the City of Zagreb, which covers an area of 180 km² (Mihalić and Arbanas, 2013). The elevations in this area range from 115 to 612 meters above sea level, and the prevailing slope angles (62%) range from 5° to 20°. The pilot area is located in the area composed of Late Miocene and Quaternary sediments. Landslides are a dominant geomorphological process in all the Medvednica Mt. stream catchments. Moreover, landslides are the main geological hazard of the studied hilly areas where approximately 32% of the urban area is located (Mihalić Arbanas et al. 2012).

The subject of this paper is the extreme weather conditions in the winter of 2013, i.e., long-lasting heavy rainfall and a thick snow cover, which triggered more than 60 landslides in the City of Zagreb. Landslides caused significant damages to private houses, infrastructure and crops. Measurements obtained by six weather stations located in the hilly area of Zagreb City were used to analyze precipitation conditions that triggered numerous landslide events. Preliminary analysis of data from one meteorological station located in the City of Zagreb, i.e. Zagreb-Grič Station shows that from the 1st January to the 7th April, the City of Zagreb experienced a period of intense rainfall and snow with cumulative values over the 97-day period exceeding 400 mm. Cumulative precipitations for the selected period exceeded 46% of the mean annual precipitation (MAP). The results of preliminary analysis of the relationship between landslide occurrence and climate conditions, shows the following extremes: cumulative monthly precipitation in January, February and March in 2013 was two to three times higher than the average monthly values for the period from 1862 to 2012; and cumulative precipitation for a 3-month period in 2013 has the highest value in the last 150 years (Bernat et al., in preparation).

Rough data about landslide events are received from records of the City Office of Emergency Management (OEM). Information regarding the (re)activation of landslides in the winter period of 2013 was received from citizens who informed City administration responsible for landslide remediation or civil protection throughout that time period. City representatives performed more than one hundred field examinations to estimate whether or not structures and/or people were at risk and to organize urgent mitigation measures. Evidence of examined landslides is recorded in the City offices in the form of lists with the data regarding landslide locations and the date of activation. On the basis of information collected from City administration, landslide inventory map with more than 60 landslides is made. Simple GIS database with reliable landslide records about location, date of initiation and landslide area will be developed on the basis of field examinations by professional engineering geologists. Results of the analysis of the relationship between landslide occurrence and climate conditions will have scientific as well as practical application for the prediction of landslides in extreme climate change scenarios.

In Croatia there are no established national or regional landslide inventories, which can gather records about landslides related to particular triggering event. Establishment of the system of centralized data archiving was initiated in April 2013 by scientists from University of Zagreb and University of Rijeka. National Protection and Rescue Directorate of the Republic of Croatia will be leading authority in organizing data collection from the whole country.

References


Address for correspondence:

Author’s Name: Sanja Bernat
Institution: Faculty of Mining, Geology and Petroleum Engineering, University of Zagreb
Address: Pierottije 6, 10000 Zagreb, Croatia
Phone: +385 1 5535 760
E-mail: sanja.bernat@rgn.hr
A deep structural borehole on Medvednica hilly zone – review of new data and possible reinterpretation of existing geological model

Željko Miklin, Tomislav Novosel, Laszlo Podolszki, Jasmina Martinčević Lazar
Croatian Geological Survey, Croatia, 10 000 Zagreb, Sachsova 2

Location of new deep structural borehole was planned with aim to cover all lithostratigraphical units, from the youngest to the oldest one. According to preliminary geological profile, made for the purpose of Detailed Engineering Geology Map of Podsibme Urban Area in scale of 1:5000, the thicknesses and depths of sediments were estimated as follows: Quaternary sediments (Q) on 45 m, the upper part of Upper Pontian sediments (M7) on 60 m, the lower part of Upper Pontian sediments (M6) on 145 m, the Lower Pannonian sediments (M5) on 160 m, the Upper Pannonian (M4) sediments on 20 m, sediments of Sarmatian (M3) on 20 m and of Badenian (M2) on 110 m. The real thicknesses of deposits were measured after drilling and they differ in some way from those that have been estimated. Core inspection revealed all lithostratigraphic units mentioned above, but with different thicknesses: Quaternary sediments with 10.2 m, the upper part of Upper Pontian sediments with 42.8 m, the lower part of Upper Pontian sediments with 127.0 m, the Lower Pontian sediments with 50.0 m, the Upper Pannonian sediments with 86.3 m, the Sarmatian sediments with 14.7 m and Badenian sediments with thickness of 19.0 m. Quaternary sediments are characterized by alteration of clayey silts and silts enriched on Fe-Mn concretions. At the depth of 9.6-10.1 m a presence of quartz pebbles was noted. The contact with sediments in the base is sharp and erosional. Similar sediments were found in the wider area of Medvednica hilly zone and their stratigraphical position was based on the analyses of pollen content. The upper part of Upper Pontian sediments is represented by yellowish to reddish brown and grey to dark gray clayey and silty sands. They are enriched on micas, and in places with Fe-Mn concretions. Within a certain interval limonite (28.1-28.2 m) and calcite crust (13.0-16.6; 33.5-33.7 m) were noted. These sediments are usually horizontally laminated, but in places they are massive. They belong to the environment of delta which intruded into the shallow brackish lake. Stratigraphical age has been determined on the basis of fossils among which the most abundant were molluscs and ostracods. According to the name of most abundant mollusc, these sediments are also known as the “Rhomboidea deposits”. Lower part of Upper Pontian sediments is composed of silts rich with calcite and silty marls with typical grey or greyish colour. They are mostly massive although at the end of this interval they are characterized with horizontal bedding and in alteration with thin layers of sands. They are the result of sedimentation which took place in border conditions, deep to the shallow environment. Sedimentation circumstances were proved by the existence of certain macro and microfossils. At the boundaries between Lower Pontian and Upper Pannonian there are transition deposits which consist of dark grey massive marls. They were deposited in deep, brackish lacustrine environment and contain a rare plant particles and shell fragments. Sarmatian deposits are characterised as medium sorted grainstone. Except carbonates, the presence of quartz, quartzite and cherts with numerous fossil particles (benthic foraminifera, fragments of seaweeds, ostracods, molluscs, shells, etc.) was noted. A detailed mineralogical analysis revealed a large amount of smectite clay minerals. As a result of their specific crystal structure they are very sensitive to shrinking and swelling. Badenian sediments are represented with heterogeneous lithotamnium limestones which are predominantly composed of peloids with presence of biofragments, such as: shells of molluscs, ostracods, particles of seaweed and benthic foraminiferas. The size of the fragments is between 0.2-0.4 mm. Limestones are poorly sorted, recrystallised with micritic to microsparitic matrix. New structural borehole revealed real thicknesses of geological units and this new data is important in better understanding of the geological structure of Medvednica hilly zone (Fig. 1).
Fig. 1 Geological profile with estimated thicknesses of geological units: (a) preliminary profile and (b) reinterpreted profile after drilling, with real thicknesses of geological units

Address for correspondence:
Author’s Name: Željko Miklin
Institution: Croatian Geological Survey - CGS
Address: Milana Sachs 2, 10000 Zagreb, Croatia
Phone: +385 1 616 0771
E-mail: zeljko.miklin@hgi-cgs.hr
Stereoscopic analysis of landslides on the southern slopes of the Mt. Medvednica and landslide features assessment – examples and field check

Laszlo Podolszki(1), Snježana Mihalić Arbanas(2), Željko Arbanas(3), Željko Miklin(1), Jasmina Martinčević Lazar(1)

(1) Croatian Geological Survey, Croatia, 10 000 Zagreb, Sachsova 2
(2) Faculty of Mining, Geology and Petroleum Engineering, Croatia, 10 000 Zagreb, Pierrotijeva 6
(3) Faculty of Civil Engineering, Croatia, 51 000 Rijeka, Viktora Cara Emina 5

The term landslide comprises almost all varieties of mass movements on slopes. Landslide inventory contains data about landslides on certain area. Landslide inventory map shows the locations of the landslides and can contain other additional data. Landslide maps can be prepared using different techniques. Landslide inventory maps are usually used in determination of landslide mitigation measures, civil engineering and urban planning. Spatial distribution of landslides and their activity is subject of change during time and that is a reason for development of landslide inventory maps from different periods (can be done by stereoscopic analysis of photographs from different periods). Data in landslide inventory is one of the most basic and most needed in further analysis in landslide susceptibility, landslide hazard and landslide risk. Most widespread and most used method in landslide inventory development is geomorphological mapping of terrain and usage of different methods of remote sensing (for example stereoscopic analysis). Even today, use and stereoscopic analysis of aerial photography has defined a prevailing standard and a benchmark against which new technologies to detect and map landslides are compared. Analytic hierarchy process (AHP) is a structural technique for data organization and analysis used for obtaining complex decisions. AHP can be used practically in landslide mapping and assessment of characteristic landslide features. Stereoscopic analysis was used in combination with AHP methodology for the assessment of characteristic landslide features on the southern slopes of the Mt. Medvednica. Assessment of characteristic landslide features for the identified landslides was based on the visible landslide features on photography (stereoscopic analysis), which included assessment of: landslide features (features at landslide body, features of landslide body boundary and features at main scarp) and features at landslide body toe part, slope morphology and land cover. Identified landslides were classified based on visible landslide features and according AHP score. Investigation encompassed: (i) criteria development for application of AHP methodology in area of research (100 km²), (ii) interpretation of 130 aerial photos of two generations, (iii) landslide inventory development and preparation of landslide inventory map and (iv) methodology verification on the basis of comparison with existing data and field check. In the paper some characteristic examples of identified landslides on the southern slopes of the Mt. Medvednica determined by stereoscopic analysis are given, with AHP score and field report. The methodology presented in this paper (stereoscopic analysis in combination with AHP methodology), is used for the first time in Croatia in landslide inventory development and preparation of landslide inventory map. Also the methodology and the established criteria is applicable in landslide inventory development and preparation of landslide inventory map in other areas where landslides exists in same or similar conditions, in Croatia or worldwide. Since there is no uniform landslide inventory for the whole territory of Croatia, the used methodology and the developed criteria also can be used as guidelines for the usage of remote sensing in landslide inventory development on national level.

Address for correspondence:
Author’s Name: Laszlo Podolszki
Institution: Croatian Geological Survey - CGS
Address: Milana Sachsa 2, 10000 Zagreb, Croatia
Phone: +385 1 6144 701
E-mail: laszlo.podolszki@hgi-cgs.hr
Geohazard a Part of Innovative Inspire Compliant Cloud Based Infrastructure - InGeoCloudS

Martin Podboj, Jasna Šinigoj
Geological survey of Slovenia, Ljubljana, Slovenia

Our actions are not adapting fast enough to exponential growth of Geo-spatial data, processes and applications quality and quantity on one side and slow progress of resources available and data visibility, accessibility and sharing on the other.

„Inspired Geodata Cloud Services“ (InGeoCloudS) project is a potential solution in that direction. The purpose of InGeoCloudS project is to demonstrate that a cloud infrastructure can be used by public organizations to provide more efficient, scalable and flexible services for creating, sharing and disseminating spatial environmental data. This is done in an innovative and standardized way. The cloud infrastructure of InGeoCloudS project is based on existing solutions available in the global market. The InGeoCloudS project provides the necessary services following a Service Oriented Architecture (SOA) principle INSPIRE compliance and adapts the most relevant standards as promoted by the Open Geospatial Consortium (OGC). These services (WMS, WFS, WPS) and standards (like GML) support geospatial interoperability, necessary to answer INSPIRE challenges and allow creation of innovation in the geo-information services. In particular, open-source tools proposed by OSGeo like Mapserver and PostGres/PostGis are pushed to the cloud and are seamlessly used by all of the proposed services. Management of groundwater resources and management of natural hazards, particularly those related to the soil and subsoil, earth quakes and landslides are taken as illustrative domain fields.

Geohazard use case is designed and built in a cloud infrastructure (InGeoCloudS) by Geological survey of Slovenia for Administration of the Republic of Slovenia for Civil Protection and Disaster Relief and public agencies in the spatial-environmental field. It provides an efficient, flexible scalable and in all ways innovative infrastructure for Geodata services.

Geohazard use case is predicting the areas where the probability of triggering landslides is increased due to higher precipitation levels. The endangered zones are predicted using the combination of a landslide susceptibility model, precipitation forecasts and landslide triggering threshold values.

Address for correspondence:
Author’s Name: Martin Podboj
Institution: Geological Survey of Slovenia
Address: Dimičeva ulica 14, Ljubljana 1000, Slovenia
Phone: +386 1 2809 824
E-mail: martin.podboj@geo-zs.si
Project MASPREM an early warning system for landslide

Marko Komac, Jasna Šinigoj, Tina Peternel, Mateja Jemec-Auflič, Matija Krivic, Maja Krajnik, Špela Kumelj, Mitja Požar
Geological survey of Slovenia, Ljubljana, Slovenia

Approximately one third of Slovenia territory is at least highly exposed to slope mass movements due to morphology, geological and tectonic conditions. In the past years intense short and long duration rainfall events caused numerous shallow landslide occurrences that are predominant type of slope mass movements in Slovenia. Although landslides are very locally related problem, the 15-years average landslide damage represents 7.6% of total damages due to disasters in Slovenia (and 0.03% of GDP). In the past 15 years more than 10 people have been killed in landslide events. Yet, consequences (and the loss of lives) could be mitigated, in some cases even prevented with a reliable near real-time landslide hazard forecast system that would continuously draw information from three data/model pillars: the precipitation forecast model, the landslide susceptibility model and the rainfall triggering values for landslide occurrence.

In the frame of the national project MASPREM, set up by the Administration of the Republic of Slovenia for civil protection and disaster relief and the Ministry of Defence of the Republic of Slovenia, the minimisation of the landslide hazard potential was a priority.

The main goal of the project was development of a near automated, real-time, online, publicly available landslide forecasting system at the national level. The system is fully operational from September 2013, yet due to the testing phase of hazard model prediction, the results need to be treated with care and within their reliability.

For the purpose of model development the first stage was to upgrade landslide susceptibility model of Slovenia at scale 1:250 000. The landslide susceptibility model was upgraded for the whole Slovenia of approximately 21,000 square kilometres. For the five selected Slovenian municipalities exposure maps of inhabitants, buildings and different types of infrastructure to potential landslides were produced. Exposure maps were elaborated based on synthesis of analysis of event-based landslide inventory and field investigations. Finally the dynamic forecasting model of early warning system for landslides was developed. Dynamic module for landslide hazard forecast (Fig. 1) integrates static and dynamic input data.

![Fig. 1 Symbolical overview of the data used for dynamic module for landslide hazard forecast](image-url)
Static input data are represented by an upgraded landslide susceptibility map at scale 1:250 000 and landslide triggering threshold values, meanwhile the dynamic input data is composed of 24-hour rainfall forecast data which are provided from Environmental agency of Republic of Slovenia. All the input data are implemented through separate modules. The automated landslide forecasting system is updated daily and classified into 6 levels of landslide hazard. Level 1 represents areas with negligible hazard to potential landslide occurrence, meanwhile level 6 represents areas with the highest level of hazard to potential landslide occurrence.

The development of a real-time early warning system for landslides presents a beneficial to various stakeholders, local authorities and relevant government agencies. The main purpose of developed early warning system for landslide is providing early warning and alerting the authorities as well as the public that is located in the potential high landslide hazard areas triggered by heavy or long lasting rainfalls.

**Address for correspondence:**

Author’s Name: Tina Peternel  
Institution: Geological Survey of Slovenia  
Address: Dimičeva ulica 14, Ljubljana 1000, Slovenia  
Phone: +386 1 2809 813  
E-mail: tina.peternel@geo-zs.si
Landslides, distribution and their consequences in the Tirana area

Ylber Muceku(1), Mentor Lamaj(2)

(1) Institute of Geosciences, Water, Energy and Environment, Polytechnic University of Tirana, Albania
(2) Geological Survey of Albania

In this paper is shortly describes the distribution and their consequences of the landslides in the Tirana area. The results are discussed here are taken from a detailed engineering geological mapping on scale 1:25000 carried out on Tirana area (Muceku et al. 2008). Mostly of Tirana area represents a hilly territory and it is situated in active seismic region. From the engineering geological and geotechnical studies was concluded this area is much affected from landslides occurrences, as well as, a considerable slopes are in unstable conditions. The landslides occurrences in this region are closed related to lithology characteristics of rocks and soils, geomorphology, physical and mechanical properties of rocks and soils, hydrological conditions, tectonics, rainfalls and seismicity activities. Geomorphologically, about 80% of the studied area is represented by hilly morphologically unit with various features such as escarpment, drains, concave and convex slopes, small flat areas with extent and type of vegetation etc. The height ranges from about 150-400m up to 1000.0m, with some hills rising up to more than 1613m (M. Dajti) above sea level. In general the slope angle of the hills ranges from 10°-20° in north western hills and 20° up to 35°-40° in east and southern hills. They are built by limestone (hard rocks), flysch and molasses rocks (soft rocks). The limestone’s rocks extend in eastern part of Tirana area. They are composed of thick strata up to massive, which in upper part of lithological profile are intensively fractured. The flysch rocks that are combination of marl, clays marls, carbonated clays and sandstones layers, are located in east and south of studied area. In general these formations on surface are intensive weathered and covered from soils deposits, which are 1.5-3.5m up to 6.0-10.0m thick. The molasses rocks extend in centrum and west of the studied area. These rocks built the folder’s structures with anticline syncline of low level, extending northwest to southeast. They are composed of clay stones, siltstones strata intercalated by sandstone layers. Also, these formations are intensively weathered in upper part of lithological profile and occupied by soils deposits. The mapped landslides on studied area are classified in accordance of the classification of Cruden and Varnes (1996). So, the dominant style of landsliding observed in the Tirana area were earth flow and rotational failures; these are particularly prevalent on slopes in the molasses and flysch rocks. Also, in some places in east of studied area within the limestone’s formations was recorded the rocks fall type. In total, 158 landslides were mapped on the studied area, which is equated to a total area of land sliding of 2.99km². Landslides have occurred within limestone’s rocks are approximated about 6.8%, and on flysch rocks 29.3% of the observed landslides respectively. Further analysis of the data collected shows that molasses rocks are the most landslide-prone lithological types within the survey area. They account for 63.9% of the total area of land sliding. As results of the landslides occurrences last 30 years in the Tirana region are demolished 78 buildings (1-2 store) and 183 others are affected by joint failure and cracks, which really has been a serious threat to human life for people who live in this area. The mass movement has affected transportation corridors and communication facilities, as well as are lost about 2.7ha agriculture area.

Address for correspondence:

Author’s Name: Ylber Muceku
Institution: Institute of Geosciences, Water, Energy and Environment, Polytechnic University of Tirana
Address: Don Bosko 61, Tirana, Albania
Phone: +355 42 2259540
E-mail: mucekuy@yahoo.com
The Influence of Anthropogenic Interventions on the Risk and the Degree of Damage to the Land and Buildings in Bosnia and Herzegovina

Hamid Begić
Federal Bureau of Geology, Sarajevo, Bosnia and Herzegovina

Stranjani village is situated about 10 km from the town of Zenica, and associated regional road Zenica-Vitez. Stranjani mine is located between the streambed stakes and slopes, upstream of the subject parcel office. The village is located cheekbones and input shaft for underground mining operations at the mine Stranjani therefore listed Mine is located in the village. Lowest morphology is a stream that drains the stakes surrounding water with higher levels hypsometrical.

Of alluvial plain, to lower the level of erosion, there is erosion teresasti elbow, narrower or wider depending on erosion and accumulation of soil. At a lower level of erosion, this stream is a relic of the terraces. Lower levels of erosion, broad terrace cropping crook formed relic middle terrace creek quite destroyed erozino denudacionim processes. At this level, the dominant clay, have their foundation in the lower level of erosion. Undermining or overload occurs above support their movement, such as Depo tailings.

Area Stranjani in geological terms is a small fraction of the Central Coal Basin. Its geological structure is similar to other parts of Central Basin. Within the basin, there are several lithostratigraphic units as the Miocene, Pliocene and Miocene.

Širokočelan mining method - wide cellae was laid after the fall of the layer with the progress by providing layers, with work in the rooftop part, with the overthrow of coal belt when overlaid and destruction of overlying rocks and the mining sequence ranged from border fields to shipping routes. In this way, essentially caving method does not change, only the details for other locations, and HEAD elements dimensioned method does not change.

Today, the traces are evident striking deformation on the surface, as well as residential and auxiliary buildings in the village of cheekbones. Resolving the relationship of participation in the degree of damage caused is a complex job, requiring dubious analytical processing of all documents, long kept litigation between mine Zenica and damaged.

Keywords:
methods of coal mining, deformation, participation in the degree of deformation fee damaged

Address for correspondence:
Author’s Name: Hamid Begić
Institution: Federal Geological Survey
Address: Ustanička 11, 71320 Ilidža, Bosnia and Herzegovina
Phone: +387 61 316 914
E-mail: begichamid@gmail.com
Author index

Alen Baraković, 29
Almin Đapo, 24
Barbara Karleuša, 40, 44
Bilandžija Darija, 36
Bogunović Igor, 36
Boško Pribićević, 24
Branko Kordić, 21, 24
Chunxiang Wang, 23, 27, 37
Čedomir Benac, 46, 58
Duje Kalajižić, 46
Duncan Whyatt, 44
Eisaku Hamasaki, 27
Elvis Žic, 40, 43, 49, 50
Gemma Davies, 44
Gen Furuaya, 21, 23, 37
George-Catalin Silvas, 28
Goran Vlastelica, 17, 21, 23, 24, 35, 57
Goran Volf, 40, 43
Hamid Begić, 69
Hideaki Marui, 9, 23, 27
Hiroshi Fukuoka, 21
Hiroyuki Yoshimatsu, 27
Igor Ružić, 40, 46, 48
Ivan Marović, 46
Ivana Sušanj, 40, 52
Ivica Kisić, 56
Ivo Andrić, 35, 57
Jasmina Martinčević Lazar, 17, 62, 64
Jasna Šinigoj, 65, 66
Josip Peranić, 19, 20
Josip Rubinić, 38
Kaoru Takara, 38
Karolina Gradiški, 15
Kisić Ivica, 36
Kyoji Sassa, 19, 20, 38
Laszlo Podolszki, 17, 62, 64
Luka Babić, 24
Maja Krajnik, 66
Maja Oštrić, 38
Marin Govorčin, 24
Marko Komac, 66
Martin Krkač, 13, 15, 27, 37, 60
Martin Podboj, 65
Martin Zidarić, 58
Martina Baučić, 57
Martina Vivoda, 19, 20, 46
Mateja Jemec-Auflič, 66
Matija Krivic, 66
Mentor Lamaj, 68
Milan Vrtnunski, 25
Miro Govedarica, 25
Mitja Požar, 66
Naoki Watanabe, 23, 37
Naoko Kimura, 56
Nedim Suljić, 32
Nenad Bičanić, 49
Nevena Dragičević, 40, 44
Nevenka Ožanić, 10, 40, 43, 44, 46, 48, 49, 50, 52
Nino Krvavica, 40, 48, 54
Ognjen Bonacci, 34, 35
Osamu Nagai, 19
Petra Đomlija, 58
Predrag Miščević, 21, 57
Sabatino Cuomo, 49
Sabid Zekan, 29
Sanja Bernat, 13, 15, 17, 58, 60
Sanja Dugonjić Jovančević, 19, 20, 46
Satoshi Yamamoto, 37
Shigeo Fujiki, 50
Shotar Kurokawa, 50
Snježana Knezić, 57
Snježana Mihalić Arbanas, 13, 15, 27, 37, 58, 60, 64
Šefika Alajbegović, 29
Špela Kumelj, 66
Takeshi Kato, 27
Tina Peternel, 66
Tomislav Novosel, 62
Toni Nikolić, 31
Vanja Travaš, 54
Vedran Jagodnik, 19, 20
Vladimir Pajic, 25
Ylber Muceku, 68
Yosuke Yamashiki, 35, 48, 50, 56
Željko Arbanas, 19, 20, 64
Željko Miklin, 17, 62, 64