

## **IPL-184 Project Annual Report 2015**

1 January 2015 to 31 December 2015

1. Project Title: **Study of landslides in flysch deposits of North Istria, Croatia: sliding mechanisms, geotechnical properties, landslide modeling and landslide susceptibility (IPL-184)**

2. Main Project Fields:

Select the suitable topics. If no suitable one, you may add new field.

(1) Technology Development

A. Monitoring and Early Warning, **B. Hazard Mapping, Vulnerability and Risk Assessment**

(2) Targeted Landslides: Mechanisms and Impacts

A. Catastrophic Landslides, B. Landslides Threatening Heritage Sites

(3) Capacity Building

A. Enhancing Human and Institutional Capacities

B. Collating and Disseminating Information/ Knowledge

(4) Mitigation, Preparedness and Recovery

**A. Preparedness, B. Mitigation, C. Recovery**

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Core members of the Project

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3. Objectives:

Study of triggering factors and landslide mechanisms of instabilities in flysch formations in North Istria, Croatia; Laboratory analyses of soil materials from flysch deposits using ring shear apparatus; Modeling of typical instabilities in flysch deposits: back analyses; Identification of conditions that caused landslides in flysch deposits; Recommendations for landslides susceptibility and hazard mapping in flysch areas.

4. Study Area:

Flysch Paleogene Basin in the north part of the Istrian Peninsula, Croatia

5. Project Duration: 4 years + 2years

6. Report

1) Progress in the project:

Activities of the 1<sup>st</sup> stage inside the IPL-184 Project are completed in 2012 and 2013 and collected data are supplemented during recent landslide investigations. The collected data for the studied landslides contain basic information about the location, type, dimensions and time of occurrence, slope angle, superficial deposit thickness and landslide triggering factors. It was observed that landslides on flysch slopes have multiple styles and retrogressive distribution, and in most cases they are rotational landslides, whereas other types of instability are rare. Instabilities are caused directly by the weathering of superficial flysch deposits exposed to atmospheric activity and unfavorable hydrological conditions that causes the shear stresses to exceed the soil strength and initiates the sliding. Landslides in the area are mostly caused by the rainfall. Furthermore, during this stage, methodology for landslide susceptibility and landslide hazard assessment was accepted. The activities inside the IPL-184 Project, conducted in the last 2 years, include establishment of the geotechnical properties data base as well as the landslide inventory establishment. The main activities in this 2<sup>nd</sup> stage of the Project included inspection of the available documentation about geotechnical characteristics of the flysch deposits from the existing geotechnical reports and remediation projects, soil sample collection, laboratory testing of collected samples, and establishment of landslide numerical models based on performed back analyses as well as laboratory testing results. Laboratory testing of soil materials from flysch deposits included ring shear apparatus testing. The special attention was given to laboratory testing and analyses of

flysch materials at different stages of weathering processes. These activities are significantly enhanced after purchasing of new laboratory equipment in Geotechnical Laboratory of the Faculty of Civil Engineering University of Rijeka in 2015. Data gained from these analyses are included in the geotechnical data base, which will also contain data from the available geotechnical reports.

## 2) Planned future activities or Statement of completion of the Project:

Future activities inside the IPL-184 Project, planned in the next 12 months, will include the part of 3<sup>rd</sup> and 4<sup>th</sup> stages and will encompass spatial analyses of geotechnical model, spatial analyses of existing landslide distribution (landslide inventory) and landslide susceptibility and hazard mapping in one pilot area in the study zone based on results of previous investigations. All activities of from first and second stages will be continued, especially laboratory testing of weak rock mass materials from flysch deposits. The main activities in the following 3<sup>rd</sup> stage of the Project which started at the end of 2014 and will continue to the end of the Project, include establishment of landslide numerical models based on performed back analyses as well as laboratory testing results. Back stability analyses will be performed to establish input parameters for the landslide numerical models. In the 4<sup>th</sup> stage which started at the end of 2015, the systematic particular deterministic analyses of landslides susceptibility based on 3D stability analyses will be carried out in for the pilot area using LS-Rapid software. The LS-Rapid software uses three dimensional models for simulation of progressive failure phenomena, developed to assess the sliding initiation and activation of landslides triggered by earthquake, rainfall or their combination. LS-Rapid aims to combine the process of landslide initiation and process of sliding mass movement (dynamic analysis), including the process of the sliding mass volume enlargement on the sliding path. Deterministic analyses will be carried out for some larger dormant landslides located near residential zones or in vicinity of important infrastructure facilities to identify landslide hazard and risk of possible reactivation of those particular landslides in extreme hydrological conditions those were observed in neighboring regions in Croatia and Slovenia in last few years.

## 3) Beneficiaries of Project for Science, Education and/or Society

As far as accomplished activities of the IPL-184 Project main beneficiaries are concerning scientists, through new scientific knowledge about:

- Landslide behavior in flysch deposits,
- Development of the methodology to determine conditions those can cause landslide triggering on flysch slopes.
- Basic assumption for the future landslide susceptibility and landslide hazard analysis.
- Possibility of reactivation of large dormant landslides located near residential zones or in vicinity of important infrastructure facilities.

These beneficiaries will also be implemented in the current student education through teaching about terrain investigation technics, landslide characteristics and mechanisms of occurrence,

landslide types and geological properties of the materials in the study area.

#### 4) Results

Results of the Project have been published in the following publications:

- Dugonjić Jovančević, S., Arbanas, Ž., Vivoda, M., Peranić, J., Đomlija, P. (2015) Landslide hazard and risk assessment in Istria, Croatia. Abstracts Proceedings of 2<sup>nd</sup> Regional Symposium on Landslides in the Adriatic-Balkan Region, (B. Abolmasov Ed.) Faculty of Mining and Geology, University of Belgrade, Belgrade.
- Peternel, T., Mikoš, M., Đomlija, P., Dugonjić Jovančević, S., Arbanas, Ž. (2015) Geological conditions of landslides in flysch deposits in Slovenia and Croatia. Abstracts Proceedings of 2<sup>nd</sup> Regional Symposium on Landslides in the Adriatic-Balkan Region, (B. Abolmasov Ed.) Faculty of Mining and Geology, University of Belgrade, Belgrade.
- Maček, M., Petkovšek, A., Arbanas, Ž., Mikoš, M., (2015) Geotechnical aspects of landslides in flysch in Slovenia and Croatia. Abstracts Proceedings of 2<sup>nd</sup> Regional Symposium on Landslides in the Adriatic-Balkan Region, (B. Abolmasov Ed.) Faculty of Mining and Geology, University of Belgrade, Belgrade.
- Arbanas, Ž., Vivoda, M., Mihalić Arbanas, S., Peranić, J., Sečanj, M., Bernat, S., Krkač, M. (2015) Analysis of a reservoir water level impact on landslide reactivation. Abstracts Proceedings of 2<sup>nd</sup> Regional Symposium on Landslides in the Adriatic-Balkan Region, (B. Abolmasov Ed.) Faculty of Mining and Geology, University of Belgrade, Belgrade.
- Mihalić Arbanas, S., Arbanas, Ž., Bernat, S., Sečanj, M., Krkač, M. (2015) Identification and mapping of the Valiči Lake Landslide (Primorsko-Goranska County, Croatia). Abstracts Proceedings of 2<sup>nd</sup> Regional Symposium on Landslides in the Adriatic-Balkan Region, (B. Abolmasov Ed.) Faculty of Mining and Geology, University of Belgrade, Belgrade.
- Mihalić Arbanas, S., Arbanas, Ž. (2015) Landslides – A guide to researching landslide phenomena and processes. In: Handbook of Research on Advancements in Environmental Engineering (N. Gaurina-Medjimorec, Ed.). IGI Global, Hershey, Pennsylvania, pp. 474-510.