

Date of Submission	
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IPL Project (IPL - 219) Annual Report Form 2019

1 January 2019 to 31 December 2019

1. **IPL – 219 (2017) Rockfall hazard identification and rockfall protection in the coastal zone of Croatia**
2. Main Project Fields
 - (1) Technology Development
 - B. Hazard Mapping, Vulnerability and Risk Assessment**
 - (2) Targeted Landslides: Mechanisms and Impacts
 - B. Landslides Threatening Heritage Sites**
 - (4) Mitigation, Preparedness and Recovery
 - A. Preparedness, B. Mitigation**
3. Name of Project leader Professor Željko Arbanas
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Core members of the Project:
 - Snježana Mihalić Arbanas, professor, University of Zagreb, Faculty of Mining, Geology and Petroleum Engineering; snjezana.mihalic@rgn.hr
 - Vedran Jagodnik, assistant professor, University of Rijeka, Faculty of Civil Engineering, Croatia; vedran.jagodnik@gradri.uniri.hr
 - Petra Jagodnik, senior lecturer, University of Rijeka, Faculty of Civil Engineering, Croatia; petra.jagodnik@gradri.uniri.hr
 - Marin Sečanj, research assistant, University of Zagreb, Faculty of Mining, Geology and Petroleum Engineering; marin.secanj@rgn.hr
4. Objectives: Study of triggering conditions and rockfall mechanisms and run out paths and processes in carbonate rocks and at along the contacts of carbonate rocks and flysch formations in Croatia; Modeling of typical historical and recent rockfalls in Croatia: back analyses; Identification of conditions that influence and cause rockfalls in carbonate rocks and at along the contact of carbonate rocks and flysch formations in Croatia; Recommendations for rockfall hazard identification and rockfall protection in the coastal zone of Croatia.
5. Study Area: Coastal zone of Croatia, City of Omiš, Vinodol Valley, Rječina Valley, North Istria
6. Project Duration: 4 years

7. Report

1) Progress in the project:

During the second year of the Project, the activities from the following phases of the Project were conducted:

1st phase: Data collection, FIELD INVESTIGATION AND SURVEY.

Field data base establishment is completed during the first year of the Project.

2nd phase: NUMERICAL MODELING.

Based on UAV photogrammetry and TLS surveys 3D digital terrain models were established for pilot sites City of Omiš (rock slopes above the city centre), rockfall Plavno at the County road 6034 near Knin in Šibensko Kninska County, rockfall Raspadalica Cliff above the railway route in Istria, rockfall Banska Vrata above the state road D403 in Rijeka and the rock slope above the Cemetery in The City of Buzet in Istria. Numerical modelling of rockfall propagation were conducted including determination of rockfall sources, rockfall propagation modeling and simulation, determination of rockfall run-offs, as well as rockfall hazard assessment. The milestone: Establishing of typical rockfall models is partially realized.

3rd phase: SPATIAL ANALYSES.

Spatial analyses of rockfalls are conducted through the study “Landslide risk assessment in the Republic of Croatia” that was prepared in joint cooperation with Ministry of Civil Engineering and Spatial Planning of the Republic of Croatia (MGIPU) and Croatian Platform for Risk Reduction where the landslide (including rockfalls) risk assessment analysis was carried out for the whole territory of the Republic of Croatia. The other comprehensive study was conducted in the frame of research “Identification and classification of landslides and erosion phenomena using the visual interpretation of the Vinodol Valley digital elevation model” PhD Thesis prepared by P. Đomlija that encompass rockfall inventory of the landslides (including rockfalls) in the pilot area of the Vinodol Valley. Both researches will enable further spatial analyses for rockfall susceptibility and hazard maps in pilot areas. The research for the purpose of rockfall susceptibility and hazard map guides preparation is started. The milestones: Rockfall susceptibility and hazard maps for the pilot areas of historical and recent rockfalls in Croatia. Recommendations for rockfall susceptibility and hazard map guides preparation are partially realized.

4th phase: ROCKFALL PROTECTION MEASURES APPLICATION.

Analysis of the assessment of most effective protection measure to reduce rockfall hazard and risk was conducted at tree pilot sites: City of Omiš (rock slopes above the city centre), rockfall Plavno at the County road 6034 near Knin in Šibensko Kninska County, rockfall Raspadalica Cliff above the railway route in Istria, rockfall Banska Vrata above the state road D403 in Rijeka and the rock slope above the Cemetery in The City of Buzet in Istria. The first two location were analyzed in details that was resulted with two design of rockfall protection. The third and fourth locations, rockfall Raspadalica Cliff and the Banska Vrata rockfall were analyzed considering the efficiency of applied protection measures (rockfall barriers). For the rock slope above the Cemetery in The City of Buzet in Istria the rockfall protection design was completed. The milestone: Assessment of the most effective rockfall protection measures and construction application and recommendations for rockfall protection measures application guides preparation are partially realized.

5th phase: RESULTS PRESENTATION.

The results of the project were presented at local, regional and state level, as well as to scientific community through: **Lectures about application of scientific results in civil protection and risk mitigation** to the *wider scientific and professional community*:

Presentation “*Protection of the City of Omiš, Croatia, from rockfall threats.*” Invited Lecture at 4th Regional Symposium on Landslides in the Adriatic-Balkan Region. Sarajevo, Bosna i Hercegovina, 2019, Arbanas, Ž.;

Presentation “*Rockfall Modelling and Rockfall Protection at the Slopes above the City of Omiš, Croatia*”, at Seminar Applied landslide research in the area of Dinarides and Pannonian Basin in Croatia. University of Florence, 18th April 2019, Arbanas, Ž.

Presentation “*Rockfall Modelling and Rockfall Protection at the Slopes above the City of Omiš, Croatia*”, at ISRM Specialised Conference „Geotechnical challenges in karst“, Omiš, Croatia, June 2019, Arbanas, Ž.

8) Planned future activities or Statement of completion of the Project

The future activities will be developed according to the Project Work Plan. In the next Project year the following activities will be carried out:

2nd phase: NUMERICAL MODELING of rockfalls in pilot areas of North Istria, Rječina River Valley and Vinodol Valley, as well as possible other recent rockfall occurrences. Numerical modelling will be conducted with the purpose of model calibration based on previously registered phenomena (block volume, parameters of restitution, trajectories, run-off).

3rd phase: SPATIAL ANALYSES. Rockfall susceptibility and hazard maps for the pilot areas of historical and recent rockfalls in Croatia (Rječina River Valley, Vinodol Valley). Recommendations for rockfall susceptibility and hazard map guides preparation.

4th phase: ROCKFALL PROTECTION MEASURES APPLICATION. Assessment of the most effective rockfall protection measures and construction application. Recommendations for rockfall protection measures application guides preparation.

5th phase: RESULTS PRESENTATION. Presentation of current results to the local authorities and stakeholders in the study area, as well as other types of Project results dissemination.

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

Society, through implementations of Project’s results in physical planning and urban areas protection (Ministry of Civil Engineering and Spatial Planning of the Republic of Croatia (MGIPU), Croatian Platform for Risk Reduction, City of Omiš). Local authorities, through better understanding of conditions of land use planning (City of Omiš). Companies those maintain facilities (highways, roads, railways, cemetery, etc.) and constructions in urban areas through identifying of rockfall hazard on existing and new facilities (City of Omiš, County Road Administration in Šibensko Kninska County, City of Buzet). Scientists, through new scientific knowledge of rockfall behavior (University of Rijeka, University of Zagreb).

10) Results:

Arbanas, Ž.; Sečanj, M.; Vivoda Prodan, M.; Dugonjić Jovančević, S.; Peranić, J.; Bernat Gazibara, S.; Krkač, M.; Udovič, D. (2019) Protection of the City of Omiš, Croatia, from rockfall threats. Proceedings of the 4th Regional Symposium on Landslides in the Adriatic-Balkan Region. Uljarević, Mato ; Zekan, Sabid ; Salković, Sabrina ; Ibrahimović, Dženan (ed.). Sarajevo, 2019. 251-255 doi:10.35123/ReSyLAB_2019

Petra Jagodnik, Vedran Jagodnik, Arbanas, Ž.; Mihalić Arbanas, S. (2019) Landslide types identified along carbonate cliffs using LiDAR-based DTM imagery – examples from the Vinodol Valley, Croatia. Proceedings of the 4th Regional Symposium on Landslides in the Adriatic-Balkan Region. Uljarević, Mato ; Zekan, Sabid ; Salković, Sabrina ; Ibrahimović, Dženan (ed.). Sarajevo, 2019. 91-96 doi:10.35123/ReSyLAB_2019_15

Arbanas, Ž.; Vivoda Prodan, M.; Dugonjić Jovančević, S.; Peranić, J.; Udovič, D.; Bernat Gazibara, S.; Krkač, M.; Sečanj, M.; Mihalić Arbanas, S. (2019) Rockfall Modelling and Rockfall Protection at the Slopes above the City of Omiš, Croatia. Proceedings of the ISRM Specialised Conference „Geotechnical challenges in karst“. Mišćević, Predrag (ed.). Split: Hrvatsko geotehničko društvo, 2019. 121-126

Sečanj, M.; Mihalić Arbanas, Krkač, M.; S. Bernat Gazibara, S.; Arbanas, Ž.; (2019) Preliminary rockfall susceptibility assessment of the rock slopes above the Town of Omiš (Croatia). Proceedings of the ISRM Specialised Conference „Geotechnical challenges in karst“. Mišćević, Predrag (ed.). Split: Hrvatsko geotehničko društvo, 2019. 347-353