

Date of Submission	
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IPL Project (IPL - 269) Annual Report Form 2023

1 January 2024 to 31 December 2024

1. **IPL – 219 (2017) Landslide Initiation, Evolution and Remediation: Physical and Numerical Modeling (LIEREM)**

2. **Main Project Fields**

(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

(5) Landslide Modeling

A. **Physical modeling**, B. **Numerical modeling**

3. **Name of Project leader:** Professor Željko Arbanas

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Core members of the Project:

Sabatino Cuomo/ University of Salerno, Department of Civil Engineering, Associate Professor; scuomo@unisa.it

Josip Peranić/ University of Rijeka, Faculty of Civil Engineering, Postdoc; josip.peranic@gradri.uniri.hr

Angela Di Perna/ University of Salerno, Department of Civil Engineering, Postdoc; adiperna@unisa.it

4. **Objectives:** Investigation of rainfall-induced landslides by combining 1g small-scale physical landslide models and advanced numerical modelling approaches; investigation of landslide initiation and propagation stages; evaluation of the effectiveness of different remediation measures such as gravity walls, piles and gabions for different slope materials and geometric conditions.

5. **Study Area:** The research activities are carried out in the Geotechnical laboratory of the Faculty of Civil Engineering, University of Rijeka and in the Geotechnical Laboratory of the Department of Civil Engineering, University of Salerno. The results will be applicable to the research topic in general.

6. **Project Duration:** 4 years

7. Report

Progress in the Project:

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

1st phase: PHYSICAL SMALL-SCALE LANDSLIDE MODELLING

Conducting 1g physical model tests of small-scale landslides with different soil types, geometric and initial moisture conditions, predefined rainfall conditions and installation of some remedial structures: PHYSICAL SMALL-SCALE LANDSLIDE MODELLING; Milestone: Obtained some of data on the hydraulic and mechanical behavior of small-scale landslides under specified test conditions. This phase will be continued in the next years of the research.

2nd phase: DATA ANALYSIS

Analysis of data collected in phase 1, including changes in soil moisture, pore water pressure (positive and matric suction), temperature and landslide/structure movement data: DATA ANALYSIS; Milestone: Analysis and interpretation of data collected from investigation in phase 1. Data Analysis is continued research based on physical small-scale landslide modeling data.

3rd phase: SOIL TESTING.

Laboratory tests for advanced hydro-mechanical characterization of soils used in small-scale physical landslide models: SOIL TESTING; Milestone: Define material properties required for the interpretation of experimentally obtained results and perform advanced numerical analyses, including: (i) classification and basic soil index properties; (ii) advanced hydraulic characterization of soils, including WRCs and HCFs; and (iii) determination of (un)saturated shear strength properties. Soil Testing is continued research during the Project period.

4th phase: NUMERICAL MODELLING

Use the obtained data to perform advanced numerical analyses (MPM) of rainfall infiltration, landslide evolution from triggering to final deposition and even landslide-structure interaction: NUMERICAL MODELLING; Milestone: Use the data obtained in phases 2 and 3 to calibrate numerical models and perform various numerical studies and parametric analyses and to assess the performance of different remediation measures.

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

The future activities will develop according to the Project Work Plan. In the next Project year, the following activities will be continued:

1st phase: PHYSICAL SMALL-SCALE LANDSLIDE MODELLING

This phase will be continued in the next years of the research.

2nd phase: DATA ANALYSIS

Data Analysis is continued research based on physical small-scale landslide modeling data.

3rd phase: SOIL TESTING.

Soil Testing is continued research during the Project period.

4th phase: NUMERICAL MODELLING

This phase will be continued in the next years of the research.

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

Landslide-affected population, practitioners and scientists dealing with landslides, through new scientific knowledge on rainfall-induced landslides; Researchers involved in the project through gaining valuable experience and knowledge in the field of conducting experiments, soil testing, numerical modelling, mitigation measures and triggering mechanisms of landslides initiated by rainfall in general; Institutions and working groups involved in the project through knowledge shearing, increasing their visibility and capacity.

10) Results:

- 1. Arbanas, Ž., Peranić, J., Jagodnik, V., Vivoda Prodan, M., Čeh, N. (2023). Remedial Measures Impact on Slope Stability and Landslide Occurrence in Small-Scale Slope Physical Model in 1 g Conditions. In: Alcántara-Ayala, I., et al. Progress in Landslide Research and Technology, Volume 2 Issue 2, 2023. Progress in Landslide Research and Technology. Springer, Cham. https://doi.org/10.1007/978-3-031-44296-4_9
- 2. Vivoda Prodan, M., Peranić, J., Pajalić, S. and Arbanas, Ž. (2023) Physical Modelling of Rainfall-Induced Sandy and Clay-Like Slope Failures. Advances in Materials Science and Engineering, 2023, pp.1–12. <https://doi.org/10.1155/2023/3234542>.
- 3. Peranić, J., Vivoda Prodan, M., Čeh, N., Škuflić, R., Arbanas, Ž. Determination of the Soil-Water Characteristic Curve of the Soil by Physical Modelling Tests. Proceedings of the 6th Regional Symposium on Landslides in the Adriatic-Balkan Region, ReSyLAB2024, Belgrade, Serbia 15–18th May 2024 / [ed. Miloš Marjanović, Uroš Đurić]. - ISBN 978-86-7352-402-3. - Vol. 6 (2024), p. 73–80. (accepted for publication)
- 4. Crescenzo, L., Peranić, J., Arbanas, Ž. et al. An approach to calibrate the unsaturated hydraulic properties of a soil through numerical modelling of a small-scale slope model exposed to rainfall. Acta Geotech. 19, 4437–4456 (2024). <https://doi.org/10.1007/s11440-023-02170-2>
- 65 Cuomo, S., Di Perna, A., Moscariello, M. et al. Possible remediation of impact-loading debris avalanches via fine long rooted grass: an experimental and material point method (MPM) analysis. Landslides 21, 679–696 (2024). <https://doi.org/10.1007/s10346-023-02178-5>.
- 6. Di Perna, A., Cuomo, S., Martinelli, M. (2023). Modelling of Landslide-Structure Interaction (LSI) Through Material Point Method (MPM). In: Alcántara-Ayala, I., et al. Progress in Landslide Research and Technology, Volume 2 Issue 1, 2023. Progress in Landslide Research and Technology. Springer, Cham. https://doi.org/10.1007/978-3-031-39012-8_6

Final and Master's Thesis Conducted as a part of the project:

- - Dora Štribec: Determination of the shear strength parameters of sand with a direct shear apparatus. Final thesis defended in July 2023 (Supervisor: Josip Peranić, PhD)

- - Rea Škuflić: Hydraulic response of a physical slope model under different rainfall intensities. Master's thesis defined in September 2023 (Supervisors: Prof. Željko Arbanas, PhD and Josip Peranić, PhD)