Date of Submission	30 March 2023

IPL Project 256 Annual Report Form

Period of activity under report
from 1 April 2022 to 31 December 2022

1. **Project Number and Title: IPL-256, Investigation of landslide initiation caused by rainfall infiltration using small-scale physical and numerical modeling (ILIRIM)**

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

   (5) Landslide Modeling

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

3. **Name of Project Leader: Josip Peranić, PhD**

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   Core members of the Project:

   Željko Arbanas/ University of Rijeka, Faculty of Civil Engineering, Head of Geotechnical Chair, Full Professor; zeljko.arbanas@gradri.uniri.hr

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4. **Objectives** (5 lines maximum): Investigate the hydro-mechanical response of slopes exposed to rainfall using a newly developed platform for testing small-scale physical landslide models under 1g conditions; Use of the data obtained together with numerical modeling to investigate the role of rainfall characteristics, hydro-mechanical soil properties, geometric and boundary conditions in landslide initiation by rainfall; Investigate the applicability of the adopted research methodology in defining rainfall thresholds.

5. **Study Area**: The research activities will be carried out in the Geotechnical laboratory of the Faculty of Civil Engineering, University of Rijeka.

6. **Project Duration**: 4 years

7. **Report**

1) Progress in the project: In the first year of the project, several slope models were built and tested under different rainfall conditions. The slope materials used so far were clean sand (as the base soil type) and sand-kaolin mixture with 10 and 15 percent kaolin in gravimetric terms. In some tests, the boundary conditions were specifically adjusted to investigate the effects of hydraulic hysteresis on the hydraulic response of the models and to test the applicability of the experimental setup in investigating the phenomena of hydraulic hysteresis. Part of the collected data related to the hydraulic response was interpreted and analysed, while the data on the movements within the slope models during the tests collected with high-speed cameras will be interpreted in the following phase of the project. Some of the tests were carried out using different methods of sensor placement to assess possible influences on the data collected. In all cases, the observations from the tests performed and the results obtained are used to modify the experimental procedure to better fit the specific objectives of the tests or to address processes under consideration. Several undergraduate and graduate students have been or are currently involved in various activities of the project and the results obtained will feed into their final or master's theses. As another proposal for a research project (uniri-mladi-tehnic-22-62, funded by the University of Rijeka) has been accepted, which includes several elements that are in line with the ongoing project IPL -256, additional sensors and monitoring elements are being integrated into the existing monitoring network.

2) Planned future activities or statement of completion of the Project: In the following one- year period, depending on the availability of the platform and other resources, some additional experiments with other soil materials and other geometric conditions should be conducted to obtain data on the hydromechanical response of models built from materials with different hydraulic conductivity while exposed to different rainfall patterns and intensities. These tests will provide valuable data that can be used in combination with different numerical modelling

techniques to investigate how different rainfall conditions affect the hydraulic response of slope models as well as their stability conditions. The results would also be valuable in quantifying the rate at which stability conditions change over time, depending on the boundary conditions to which the slopes are subjected in terms of the hydraulic and mechanical properties of the soil. Another interesting point, based on the experience so far, would be to consider different model build-up approaches to the resulting stress-strain conditions within slopes, the problem also being related to the initialization of the numerical models. Determining the hydraulic and mechanical properties of the tested soil materials for relevant loading conditions is also an important part of the investigations to be carried out in the future.

3) Beneficiaries of Project for Science, Education and/or Society: The benefit of the project from a scientific point of view is to gain new knowledge and experience in the field of modelling hydraulic and mechanical processes in slopes through physically and numerically based approaches, but also in the general knowledge of how the influence of different boundary conditions and in particular the variation of rainfall intensity affect soil moisture and pore water pressure conditions within soil slopes as well as the mechanical response and the state of stability. A better understanding of the mechanisms and processes in slopes exposed to rainfall is beneficial for practitioners and scientists dealing with rainfall-induced landslides, but indirectly also for the population affected by landslides in general. The results of the project are presented at conferences, workshops and symposia on the research topic and many students are involved in the various project activities through their work in the geotechnical laboratory of the Faculty of Civil Engineering at the University of Rijeka and through various undergraduate and graduate courses. So besides the scientific component, the educational component of the project is also relevant.
4) Results: The results of the project were published or prepared for submission in several journal papers and presented (or accepted for presentation) at the conferences, as outlined below:
   - Peranić, J., Čeh, N. and Arbanas, Ž., 2022. The Use of Soil Moisture and Pore-Water Pressure Sensors for the Interpretation of Landslide Behavior in Small-Scale Physical Models. Sensors, 22(19), p.7337. https://doi.org/10.3390/s22197337.
   - 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.
   - Calibration of the unsaturated hydraulic properties of a soil using an observational numerical modelling approach applied to a small-scale slope model test result (prep. for submission)
   - Peranić, J. The ILIRIM Project: Initial findings from the small-scale landslide model tests. Presentation at the 2022 ICL-KLC Hybrid Conference, 22-25 November 2022, Kyoto, Japan.
   - Peranić, J., Jagodnik, V., Vivoda Prodan, M. and Arbanas, Ž. (in press) Research on rainfall-infiltration induced landslides through physical and numerical modelling (In proc. of the 9th Conference of Croatian Geotechnical Society with international participation and under the auspices

of ISSMGE: *Geotehnika u epicentru – Petrinja 2020*. Sisak, Croatia, 4-6 May 2023)

- Peranić, J., Vivoda Prodan, M., Jagodnik, V., Čeh, N. and Arbanas, Ž. (submitted) Investigating the hydraulic response of a slope model under different rainfall conditions through physical modelling (submitted for presentation at the 6th World Landslide Forum)