

## IPL Project (IPL-274) Annual Report Form

**Period of activity under report  
from 1 January 2025 to 31 December 2025**

### 1. Project Number and Title:

IPL-274: Understanding the seismic response of large-scale geological hazards for developing early warning methods

### 2. Main Project Fields

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

(1) Technology Development

B. Hazard Mapping, Vulnerability and Risk Assessment

(2) Targeted Landslides: Mechanisms and Impacts

A. Catastrophic Landslides

(3) Capacity Building

B. Collating and Disseminating Information/ Knowledge

(4) Mitigation, Preparedness and Recovery

A. Preparedness

### 3. Name of Project Leader : Yifei Cui

Affiliation: Associate Professor, Tsinghua University (THU)

Telephone: +86-13520838697

Email: yifeicui@mail.tsinghua.edu.cn

Core members of the Project:

- 1) Dr. Yan Yan/Associate Professor, School of Civil Engineering, Southwest Jiaotong University (SWJTU), China
- 2) Dr. Hui Tang/ Senior Scientist, German Research Center for Geosciences (GFZ), Germany
- 3) Dr. Fan Xie/ Senior Research Scientist, Institute of Geophysics, China Earthquake Administration, China
- 4) Dr. Shuofan Wang/ Post-Doctoral Fellow, River Research Institute, Department of Hydraulic Engineering, Tsinghua University, China
- 5) Dr. Jinchang Chen/ Post-Doctoral Fellow, River Research Institute, Department of Hydraulic Engineering, Tsinghua University, China

### 4. Objectives (5 lines maximum)

Based on the laboratory experiments, numerical simulation, and field monitoring, this research aims to develop a new physical model for the seismic signal generated by mass movements considering the basal force, together with a seismic inversion model considering path effect by

improving empirical green's functions, finally propose a seismic signal based early warning system combining on-site monitoring, fast numerical simulation, and big data analysis.

## **5. Study Area**

The Parlung Tsangpo River Basin, Tibet, China; Wenchuan earthquake area, Sichuan, China; Illgraben, Switzerland

## **6. Project Duration**

2024.1-2027.12

## **7. Report**

### **1) Progress in the project (30 lines maximum)**

- i. Field investigations and monitoring deployment were carried out in the Duwen Highway area of the Wenchuan earthquake region. The team surveyed several typical debris-flow catchments, including Banzigou, Cutougou, Yeniugou, Chediguangou, Chayuangou, Xinqiaogou, Dengxigou, and Fotangbagou, and established an integrated monitoring system combining seismic, video, and hydrological observations.
- ii. A series of flume experiments further clarified the relationship among debris-flow dynamics, basal forces, and seismic signals. The study quantified the statistical characteristics of normalized basal impact forces and linked them with dimensionless flow parameters. Additional experiments revealed how basal roughness and particle composition control flow mobility, shear structure, and seismic amplitude/PSD characteristics.
- iii. Large-scale laboratory experiments on granular-flow impact against rigid barriers with retained deposits revealed two distinct interaction modes, namely pile-up and run-up. The project established seismic-signal-based criteria for identifying these impact mechanisms and demonstrated the feasibility of using non-contact seismic measurements to infer hazardous flow-structure interaction processes.
- iv. The project also developed an inversion framework that combines seismic signals and numerical simulation for landslide–tsunami hazard chains. Using seismic-force-time functions as a bridge, the framework matched real-time inversion results with a pre-built simulation database and supported rapid prediction of inundation areas.
- v. In numerical modeling, the team developed an improved Voellmy-D model to describe the landslide-to-debris-flow transition process, and further built a machine-learning-assisted rapid risk assessment framework constrained by physical simulations, greatly improving regional prediction efficiency.
- vi. In hazard detection and warning, the project advanced seismic-signal-based event recognition using deep learning, acoustic-emission picking, amplitude features, and

centroid-frequency-based methods. These approaches improved the identification and warning capability for debris flows, avalanches, and related mass-movement events.

- vii. International collaboration was strengthened through exchanges with German partners, including academic visits and joint field discussions. Two co-authored papers were produced through the China–Germany collaboration.
- viii. In total, the project published 7 papers in 2025, including 6 SCI papers; 2 patents entered substantive examination; and project members participated in 8 domestic and international academic conferences.

## **2) Planned future activities or statement of completion of the Project (15 lines maximum)**

- i. Conduct further flume and large-scale laboratory experiments to quantify how basal roughness, particle composition, retained deposits in front of barriers, and channel geometry control debris-flow/landslide dynamics, basal forces, and generated seismic signals, and use the new datasets to improve the physical interpretation of monitored signals.
- ii. Expand the inversion framework that links seismic observations with numerical simulations by constructing a larger scenario database for landslides, debris flows, and landslide–tsunami chains, and by using force-time functions derived from seismic inversion to match the most probable dynamic process and impact area in real time.
- iii. Further develop rapid simulation methods for large-scale hazards, including GPU-based computation, hybrid reduced-order/full-physics strategies, and machine-learning surrogate models, in order to improve the efficiency of hazard-range and risk assessment for near-real-time warning applications.
- iv. Validate the developed methods using field monitoring data from Chinese mountain catchments and the Illgraben debris-flow station in Switzerland, with particular focus on testing signal-based detection, process inversion, and warning performance under real events.
- v. Integrate the validated methods into a non-contact seismic monitoring and visualization system, including automatic event detection and identification based on amplitude, spectral, and deep-learning features, and complete the final international co-authored papers and project completion report.

## **3) Beneficiaries of Project for Science, Education and/or Society (15 lines maximum)**

- i. It provides new experimental and numerical tools for linking basal force, flow dynamics, and seismic signals, which benefits the broader landslide and debris-flow research community.

- ii. The outcomes support engineering practice by improving rapid simulation, hazard-range assessment, and warning strategies for mountain disasters.
- iii. The seismic-based non-contact monitoring and identification methods are valuable for early warning agencies and operators of critical infrastructure in mountainous regions.
- iv. The project promotes international academic exchange and training through joint research, co-authored papers, and collaboration with German partners.
- v. The methodologies developed in this project also contribute to future AI-assisted, physics-informed hazard warning systems for vulnerable mountain areas.

#### 4) Results (15 line maximum, e.g. publications)

- [1] Yan Yan, Hui Tang, Kailai Zhou, Jens M. Turowski, **Yifei Cui** & Bin Xiang. (2025). Statistical characteristics of basal forces generated by experimental debris flows. *Journal of Geophysical Research: Solid Earth*, 130(3), e2024JB030027.
- [2] Xinzhi Zhou, **Yifei Cui**, Jun Fang, Hui Tang, Zhen Zhang & Shuofan Wang. (2025). Link between the impact mechanisms of granular flow-dam interaction and the generated seismic signal: Insights from laboratory experiments. *Journal of Geophysical Research: Solid Earth*, 130, e2024JB029946.
- [3] Xinzhi Zhou, **Yifei Cui**, Zhen Zhang, Lingling Ye & Jun Fang. (2025). Linking dynamic parameters and seismic signals of granular flows in different flow regimes: An experimental assessment of effects of particle composition. *Journal of Geophysical Research: Earth Surface*, 130, e2025JF008354.
- [4] Jian Guo, **Yifei Cui**, Yanzhou Yin & Guodong Wang. (2025). Influence of throat topography on the kinematics of rock avalanches. *Journal of Rock Mechanics and Geotechnical Engineering*, 17(11), 7250–7264.
- [5] Dekang Li, Fan Xie, Qing-Yu Wang, Enrico Milanese, Junju Xie & Li Li. (2025). An ensemble deep learning-based acoustic emission picking model reveals migratory foreshocks on large-scale laboratory fault. *Journal of Geophysical Research: Solid Earth*, 130, e2024JB029934.
- [6] Qi Zhou, Hui Tang, Clément Hibert, Małgorzata Chmiel, Fabian Walter, Michael Dietze & Jens M. Turowski. (2025). Enhancing debris flow warning via machine learning feature reduction and model selection. *Journal of Geophysical Research: Earth Surface*, 130, e2024JF008094.
- [7] Shuofan Wang, **Yifei Cui**, Xiongtao Deng, Yao Li, Yonggang Zhang, Chunhao Wu & Jian Guo. (2026). Geological disaster event detection based on seismic signals: A case study of "23.7" Beijing flush flood and debris flow. *Reviews of Geophysics and Planetary Physics*, 57(1), 70–81 (in Chinese).

Note:

- 1) If you will change items 2-6 from the proposal, please write the revised content **in Red**.
- 2) Please fill and submit this form to **ICL Network** <[icl-network@landslides.org](mailto:icl-network@landslides.org)>
- 3) Reporting year must be one or two years (Maximum).