Date of Submission	Oct 29th, 2020

IPL Project (IPL - 230) Annual Report Form 2020

1 January 2019 to 31 December 2019

1. Project Number (approved year) and Title

   IPL-230 (2018) Title: Evolution-based key technology of landslide prevention in Three Gorges Reservoir region, China

2. Main Project Fields

   Hazard Mapping, Vulnerability and Risk Assessment; Catastrophic Landslides; Mitigation

3. Name of Project leader: Huiming Tang

   Affiliation: Vice President, China University of Geosciences (Wuhan), China.
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   Core members of the Project: Names/Affiliations: (4 individuals maximum)
   Prof. Changdong Li/ Faculty of Engineering, China University of Geosciences (Wuhan), China.
   Prof. Liangqing Wang/ Faculty of Engineering, China University of Geosciences (Wuhan), China.
   Prof. Wenping Gong/ Faculty of Engineering, China University of Geosciences (Wuhan), China.
   Dr. Miao Yu/ Faculty of Engineering, China University of Geosciences (Wuhan), China.

4. Objectives: (5 lines maximum)

   Based on the landslide geohazard research bases in the Three Gorges Reservoir region of China, this proposal aims to investigate the response characteristics of stabilizing pile embedded in landslide rock and soil masses, then the co-evolution characteristics of the landslide-stabilizing pile structure system will be further studied, afterwards key technologies of stabilizing pile design based on the evolution process will be summarized, finally the standardization of stabilizing pile design will be proposed.

5. Study Area: (2 lines maximum)

   Zigui Basin in Three Gorges Reservoir Region, China

6. Project Duration (1 line maximum)

   2017.1-2020.12.

7. Report

1) Progress in the project: (30 lines maximum)

① The deformation response and triggering factors of the reservoir landslide-pile system were investigated by a proposed novel research framework, which includes three phases: (I). monitoring results are obtained and random deformation data are generated considering uncertainty of monitoring data; (II). analyzing landslide surface and pile deformation of landslide–pile system by discretizing monitoring results and random deformation data; (III). using monitoring results and random deformation data to determine main triggering factors of deformation by geographic detector technique and analyze the interaction types of any two factors. Aimed at the Majiagou landslide, a representative reservoir landslide installed stabilizing and test piles, monitoring data of monthly rainfall, variations of reservoir water level, deformation of landslide surface and piles' head were collected, preprocessed and analyzed. The main conclusions by studying Majiagou landslide indicate that the anti-slide performance and action range of piles gradually decrease with the increase of hydraulic cycle; the deterioration of geomaterials' properties are the most important triggering factor leading to the deformation of landslide–pile system and the degradation of piles' performance.

② A probabilistic multi-objective optimization framework for landslide reinforcement with stabilizing piles was proposed and illustrated by taking the Majiagou landslide as the case study. Specifically, performance objectives related to failure probability, system robustness and life-cycle cost of the landslide-stabilizing pile system with feasible designs were evaluated, then the best compromised design was obtained by means of Pareto optimality. Expert knowledge and professional judgment were required to set necessary restrictions and finally determine the optimal design. UCS of sandstone and argillaceous siltstone sampled from the bedrock of Majiagou landslide was obtained through a series of uniaxial compression tests (40 samples for each rock type). Then probabilistic characteristics of UCS were obtained, and the probabilistic distribution of foundation coefficient K was further acquired. The seismic response of the landslide-stabilizing pile system is calculated based on the imbalance thrust method, ''K'' method and Monte Carlo simulation. The results show that there is a better design of stabilizing piles than the existing one, with which acceptable reinforcement effectiveness, compromised life-cycle cost and robust system performance can be realized. The optimal design will also vary with the concerned performance objectives and knowledge-based judgment.

2) Planned future activities or Statement of completion of the Project (15 lines maximum)

The project aims to investigate the responses of stabilizing piles embedded in reservoir landslides, to study the evolution characteristics of the landslide-stabilizing pile system, and propose key technologies for the design of stabilizing piles based on the evolution process of the landslide-stabilizing pile system. Evolution characteristics of the deformation of landslide-stabilizing

pile system have been investigated, and the evolution mechanism and triggering factors of landslide-stabilizing pile system have been revealed and identified. Moreover, a novel and integrated framework considering the life-cycle of landslide-stabilizing pile system has been for the piles design in the reinforcement of landslides. This project has led to the publication of 2 SCI papers and has cultivated 6 post-graduate students. Overall, this project has completed designed objectives well, and the produced results will play a significant important role in the prevention and mitigation of landslides.

In the future, physical model tests and numerical tests of landslide-stabilizing pile system will be conducted based on fine three-dimensional models, through which the evolution process of landslide-stabilizing pile system will be reproduced and analyzed in detail.

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

The project related researches have expanded the understanding of evolution characteristics of the reservoir landslide-pile system in terms of the deformation response, and help to identify triggering factors of the deformation of reservoir landslide-pile system. Moreover, optimization method of stabilizing piles, which combines the system performance, life-cycle cost with the probabilistic characteristics of bedrock rock mass, were proposed and thus fills in gaps in the comprehensive design scheme for stabilizing piles used for reinforcing reservoir landslides. The above research results provide scientific references not only for the researchers in related research fields but also for the residents threatened by reservoir landslides and the companies working on the prevention and mitigation projects of landslides. Finally, the proposed approaches can be popularized and applied in the prevention and control of the engineering landslides in reservoir, mine, traffic and so on, and provide guarantee for the sustainable development of society and economy.

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

The evolution characteristics of deformation response and triggering factors of the reservoir landslide-pile system were investigated through monitoring data analysis. Performance-based standards of landslide-stabilizing piles system were illustrated, and optimization methods of stabilizing piles' spatial layout and structure parameters were proposed. Based on the conducted studies, 2 SCI papers have been published and 6 post-graduate students have graduated. The detailed information about the published papers are listed as follows:

① Haikuan Zhang, **Changdong Li***, **Xinli Hu***, Zhiyong Fu, Wenqiang Chen, Wenmin Yao, Yunpeng Zhang, Xihui Jiang. Deformation response and triggering factors of the reservoir landslide–pile system based upon geographic detector technology and uncertainty of monitoring data, 2020, Stochastic Environmental Research and Risk Assessment, 2020, online. (DOI: 10.1007/s00477-020-01889-8)

② Wenmin Yao, **Changdong Li ***, Hongbin Zhan, Huawei Zhang, Wenqiang Chen. Probabilistic

multi-objective optimization for landslide reinforcement with stabilizing piles in Zigui Basin of Three Gorges Reservoir region, China. Stochastic Environmental Research and Risk Assessment, 2020, online. (DOI: 10.1007/s00477-020-01800-5)

Note:

1) If you will change items 1)-6) from the proposal, please write the revised content in Red.
2) Please fill and submit this form by 30 October 2020 to ICL Network <icl-network@iclhq.org>