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| Date of Submission | Oct. 10 th , 2022 |
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IPL Project (IPL - 230) Annual Report Form 2021

1 January 2019 to 31 December 2022

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)

Badong county and Zigui Basin in Three Gorges Reservoir Region, China

6. Project Duration (1 line maximum)

2019.1-2022.12.

7. Report

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

- ① Regarding to the evolution mechanism of reservoir landslide in the study area of Zigui Basin in Three Gorges Reservoir Region, China, five large and many small landslides are developed in Jurassic strata along the lower reaches of Xiangxi River, where interbedded weak and hard bedrock layers foster the development of landslides with a “stair-step” sliding surface. The paper investigates the evolution characteristics of these landslides and presents a novel forecasting model for their displacements. The distribution characteristics and behavior of landslides developed along Xiangxi River is revealed by the database of landslides in the larger Zigui basin, of which this area is part. Most landslides occur at rather low elevations of <300 m and in areas of moderate rainfall. The geological evolution of landslides in the Xiangxi River valley can be divided into four stages, beginning with anticline formation, followed by valley incision, then by weathering and erosion, and culminating in formation of the colluvial land-slides. The accumulative displacement curves of landslides with a stair-step sliding surface in Xiangxi River region also present obvious, step-like characteristics.
- ② In the aspect of evolution process of landslide-pile system, we develop an analytical method to design the plane arrangement of stabilising piles under spatial lateral load of 3D colluvial landslides with multilayer sliding masses. Firstly, an approach based on the geological map and binary Lagrange Interpolation method was presented to establish 3D landslide calculation models. The improved 3D limit equilibrium method was then proposed to calculate the stability coefficient and spatial distributed lateral load of landslide with multilayer sliding masses. And main sliding direction of 3D multilayer landslide can be determined by the developed principle of minimum potential energy. Moreover, through assuming the piles and soil as elastic transversely isotropic continuum medium, analytical approach was employed to accurately calculate the stress distribution of soil between adjacent piles; and the maximum pile spacing can be calculated. Finally, the reasonable arrangement of stabilising piles can be determined based on Monte-Carlo method and cost of all piles. The finite difference method was employed to validate the theoretical results through the case study of Bazimen landslide.

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

The project aims to investigate the evolution-based key technology of landslide prevention in Three Gorges Reservoir region of China based on the evolution process of the landslide. Evolution characteristics of the deformation of landslide have been investigated, and the evolution mechanism and triggering factors of landslide have been revealed and identified. Moreover, the evolution characteristics and displacement forecasting model of landslides with stair-step sliding surface was

proposed. This project has led to the publication of 3 indexed SCI papers and has cultivated 7 post-graduate students. On the whole, the project has completed designed objectives well, and the produced results will play a significant important role in the prevention of landslides.

In the future plan, more physical model tests and numerical tests of landslide will be conducted based on improved three-dimensional models with new lab test technology.

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. Five large and many small landslides are developed in Jurassic strata along the lower reaches of Xiangxi River, where interbedded weak and hard bedrock layers foster the development of landslides with a “stair-step” sliding surface. We investigate the evolution characteristics of these landslides and presents a novel forecasting model for their displacements. In the aspect of evolution process of landslide-pile system, we develop an analytical method to design the plane arrangement of stabilising piles under spatial lateral load of 3D colluvial landslides with multilayer sliding masses

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 banks, mine slopes, highway slopes, etc.

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

Based on the conducted studies, 3 SCI indexed papers have been published and 7 post-graduate students have graduated. The detailed information about the published papers are listed as follows:

- ① Yunfeng Ge, **Huiming Tang***, **Changdong Li**. Mechanical energy evolution in the propagation of the rock avalanche using field survey and numerical simulation. *Landslides*, 2021, 18, 3559-3576.
- ② DingXia, YunfengGe, **HuimingTang***, BochengZhang, PeiwuShen. SDZM: Software for determining shear damage zones of rock joints. *SDZM: Software for determining shear damage zones of rock joints. Computers & Geosciences*, February 2022, Volume 159, 105021.
- ③ **Changdong Li**, Robert E. Criss*, Zhiyong Fu, Jingjing Long, Qinwen Tan. Evolution characteristics and displacement forecasting model of landslides with stair-step sliding surface along the Xiangxi River, Three Gorges Reservoir region, China. *Engineering Geology*, 2021, 283, 105961.

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 15 December, 2022 to ICL Network <icl-network@iclhq.org>