Geoenvironmental Disasters

EDITORIAL

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Report on the international workshop on seismic design and assessment for resilience, robustness and sustainability of slope engineering, 13–15 January 2023, Shanghai, China

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Abstract

The International Workshop on Seismic Design and Assessment for Resilience, Robustness and Sustainability of Slope Engineering was held on 13–15 January 2023 on line, focusing on the theme of "Seismic resilience of slope engineering and the concept of resilience-based seismic design (RBSD) for geological disaster prevention and control". In this workshop, a number of keynote and invited lectures provided an international exchange platform for researchers, industrial engineers and students to share their research, engineering practice and exchange novel ideas on seismic resilience for slope engineering in a way of online. At the same time, during this workshop, technical committee of the ICGdR-TC1 also took this opportunity to hold a working meeting on cutting-edge and strategic issues, and released the Shanghai Declaration on slope engineering.

Organizer and supporting organizations

This workshop was organized by the College of Civil Engineering, Tongji University, China. And this workshop was also jointly supported by the International Consortium on Geo-disaster Reduction (ICGdR), the National Natural Science Foundation of China (NSFC) and the Science and Technology Commission of Shanghai Municipality (STCSM), China.

The organizing committee of this workshop included: Yu Huang (Chair); Wuwei Mao (Secretary General), Min Xiong (Secretary General), Tongji University, China.

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The international workshop on seismic design and assessment for resilience, robustness and sustainability of slope engineering

Landslides triggered by earthquake often bring serious threats to people's life, regional infrastructure and lifeline projects, resulting in huge casualties and social and economic losses. To unite experts from all over the world to deeply discuss the issues of seismic resilience, the International Workshop on Seismic Design and Assessment for Resilience, Robustness and Sustainability of Slope Engineering was successfully held at Tongji University in Shanghai, China, from 13 to 15 January, 2023. The workshop reached a lot of consensus on the topics of seismic design and evaluation of slope engineering, and issued the "Shanghai Declaration: Design for Seismic Resilience, Robustness and Sustainability of Slope Engineering".

The NSFC (National Natural Science Foundation of China), ICGdR (International Consortium on Geo-disaster Reduction), UNESCO-Chair on Geo-environmental

Disaster Reduction, and IAEG (International Association for Engineering Geology and the Environment) have provided strong support to this workshop. The International workshop on Seismic Design and Assessment for Resilience, Robustness and Sustainability of Slope Engineering were focusing on the theme of "Seismic resilience of slope engineering and the concept of resilience-based seismic design (RBSD) for geological disaster prevention and control". It was held online and attracted extensive attention from experts and scholars in related fields around the world. Scholars from more than 10 countries and regions, including China, Japan, Nepal, the United States, the United Kingdom, Germany, Austria, Italy, Australia and Ethiopia, participated in the workshop. More than 230 delegates shared the latest research results of seismic design and evaluation for resilience, robustness and sustainability of slope engineering online.

Plenary sessions of the workshop

Opening ceremony

The opening ceremony (Fig. 1) was presided over by Prof. Yu Huang of Tongji University, the Chairman of the workshop. Prof. Jianguo Ren, Director of Earth Science Department of the National Natural Science Foundation of China, attended the opening ceremony. Prof. Fawu Wang, President of the International Consortium on Geo-disaster Reduction, Prof. Rafig Azzam, President of the International Association of Engineering Geology and the Environment, and Prof. Xiaohua Tong, Vice President of Tongji University delivered congratulatory speeches. Prof. Fawu Wang pointed out that the current methods for seismic design of slope engineering have developed from empirical to resilience-based design, and the involved resilience, robustness and sustainability are the latest concepts of disaster prevention and reduction. He hoped that this workshop could strengthen international exchange and cooperation in the field of assessment and design of slope seismic response. Prof. Rafig Azzam stated that in the field of disaster prevention of earthquake-induced landslides, the research and engineering practice based on resilient disaster prevention are still in the preliminary stage, and there remains a lack of corresponding design codes and guidelines, which brings great challenges to the practice of seismic design of slope engineering based on resilience. It is expected that this workshop would provide new ideas for the study of engineering geological hazards. Prof. Xiaohua Tong extended sincere congratulations on the convening of this workshop and warmly welcomed all the representatives from all over the world to attend the workshop on

Fig. 1 Opening speech hosted by Prof. Yu Huang (**a**) and presented by Prof. Fawu Wang (**b**), Prof. Rafig Azzam (**c**), Prof. Xiaohua Tong (**d**)

behalf of Tongji University. He looked forward to the scholars attending the workshop aiming at the forefront development of slope engineering resilience and seismic resistance, extensive exchanges and discussions on relevant key scientific issues, and making new contributions to the research on disaster prevention and reduction.

Keynote lectures

More than 30 keynote presentations (Table 1) and invited presentations (Table 2) focused on major scientific issues and key technologies of aseismic design and evaluation for resilience, robustness and sustainability of slope engineering. The content of the talks covers seismic damage and fortification level of slope engineering, analysis on seismic effect of slope engineering site, evolution mechanism and analysis method of slope instability under seismic dynamic excitation, analysis theory on seismic resilience of slope engineering, the seismic robustness analysis method of slope engineering, research on the seismic method of slope engineering sustainability, the prospect of future seismic design method of slope engineering, the practice of seismic design of major slope

Table 1 Lists of the presentation in keynote lectures

No.	Title	Presenter	Affiliation
K-1	Views on sustainable disaster mitigation	*Ikuo Towhata*	University of Tokyo, Japan
K-2	S-FEM coupled with phase-field for fracture initiation and propagation in rocks	*Guirong Liu*	University of Cincinnati, US
K-3	Machine learning powered coseismic landslide detection	*Limin Zhang*	The Hong Kong University of Science and Technology, Hong Kong, China
K-4	Numerical simulation on model tests of slope failure in unsaturated Sirasu ground—an application of THMA coupling analysis in FE-FD scheme under the condition of constant temperature	*Feng Zhang*	Nagoya Institute of Technology, Japan
K-5	Three types of liquefaction in landslides triggered by earthquake	*Fawu Wang*	Tongji University, China
K-6	Method to substitute threshold criterion of monitoring and early warning in landslides	*Rafig Azzam*	RWTH Aachen University, Germany
K-7	On the landslide-triggering ground motions on slopes during earthquakes	*Gonghui Wang*	Kyoto University, Japan
K-8	Seismic response characteristics and deformation evolution of the bedding rock slope using a large-scale shaking table	*Shengwen Qi*	Institute of Geology and Geophysics, Chinese Academy of Sciences, China
K-9	Physics-based and empirically based coseismic landslide analyses	*Gang Wang*	The Hong Kong University of Science and Technology, Hong Kong, China
K-10	Responsive particulate materials-rheology, mechanism, and potential applications in slope engineering	*Jin Sun*	The University of Edinburgh, UK
K-11	Geological and geotechnical risks for offshore wind farm	*Subhamoy Bhattacharya*	University of Surrey, UK
K-12	General framework for seismic resilience assessment of slope engineering	*Yu Huang*	Tongji University, China
K-13	Toward real-scale DEM simulations of landslide: periodic granular box for initializing slope geometry	*Jian Chen*	Japan Agency for Marine-Earth Science Technology, Japan
K-14	Effect of initial water content and dry density on the dynamic responses of unsaturated embankments	*Guanlin Ye*	Shanghai Jiao Tong University, China
K-15	Reliability evaluation of reservoir bank slopes with weak interlayers considering influence of multiple triggering factors and spatial variability	*Wengang Zhang*	Chongqing University, China
K-16	Research on the mechanism of reservoir dam break induced by coupled earthquake and rainstorm: a case study of the Gouhou rock fill dam failure	*Aiguo Xing*	Shanghai Jiao Tong University, China
K-17	Run-out distance evolution of earthquake-induced landslide under different fluctuation scales of strength parameters	*Weijie Zhang*	Hohai University, China
K-18	Effects of particle size distribution on run-out distance of granular flow	*Shuji Moriguchi*	Tohoku University, Japan
K-19	Analysis of seismic-induced slope damage by random discrete element modelling	*Tao Zhao*	Brunel University London, UK

Table 2 List of the presentation in INVITED Lectures

No.	Title	Presenter	Affiliation
I-1	A stable and efficient meshfree method for simulating large-deformation landslides	*Zirui Mao*	University of Cincinnati, US
I-2	Investigations of earthquake-induced failure of jointed rock slopes using the hybrid finite-discrete element method	*Qi Zhao*	The Hong Kong Polytechnic University, Hong Kong, China
I-3	Seismic reliability analysis of slopes based on data-driven method	*Rui Pang*	Dalian University of Technology, China
I-4	Earthquake-induced permanent displacement of slope with multiple sliding planes	*Jian Song*	Hohai University, China
I-5	Probabilistic approach to the performance-based seismic assessment of retaining structures	*Hongqiang Hu*	Zhejiang University, China
I-6	Coriolis effect in centrifuge modeling of the post-failure flow behavior of slope	*Bei Zhang*	Chang'an University, China
I-7	Unsteady motion process of landslide debris flows characterized by micro-seismic signals	*Wuwei Mao*	Tongji University, China
I-8	Multi-objective optimization design of pile-anchor structures for slopes considering the spatial variability of soil properties	*Zhengying He*	Tongji University, China
I-9	Research on large displacement shear characteristics of sand particles affected by high temperature	*Suran Wang*	University of Shanghai for Science and Technology, China
I-10	Steady granular rheology subject to coexistence of multiple regimes	*Chongqiang Zhu*	University of Dundee, UK
I-11	Modelling large deformation slope failure with Smoothed Particle Hydrodynamics (SPH)	*Ruofeng Feng*	The University of Manchester, UK
I-12	Thermal property improvement of slope stabilized by cement mixing technology	*Benyi Cao*	University of Surrey, UK

engineering projects and other related research fields (Fig. 2).

ICGdR-TC1 held a special working meeting on 14 January, 2023. This meeting was chaired by Professor Yu Huang, Chairman of the Committee. Experts at the meeting agreed that seismic design of slope, as a key means of landslide prevention and control, has gradually carried out research on seismic design based on resilience, robustness and sustainability, but there are still many challenges in the design and evaluation of seismic resilience of slope engineering. In particular, the concept of resilience in the field of slope engineering lacks a unified understanding and has not formed a global framework and guide. Given the above issues, the expert committee reached a widely consensus after full discussion and adopted the Shanghai Declaration ("Appendix: Resolution on slope engineering") initiative initiated by Tongji University (Fig. 3).

Closing ceremony

At the closing ceremony of the workshop on 15 January, "Shanghai Declaration on the Seismic Resilience, Robustness, and Sustainability of Slope Engineering" was released, which was unanimously agreed upon by the delegates. The declaration sets out five key tasks and eight major goals to be achieved by 2030 for the future development of slope seismic engineering worldwide. The declaration ("Appendix"), based on advanced monitoring methods, ecological engineering design concepts and the requirements for sustainable seismic design of slope engineering, is issued to relevant management departments, enterprises and research institutions around the world. The experts at the meeting hoped to increase the global community's attention and research depth on the development of seismic resilience of slope engineering, so as to promote the practice of seismic resilience design of slope engineering, reduce the risk and impact of slope failure and landslide disaster, and proposed a new generation of seismic resilience design and evaluation guidelines for slope engineering, to ensure long-term stability and safety of slope.

Through this workshop, scholars all over the world fully exchanged and shared the latest research results and ideas, and put forward many creative questions and suggestions. It is generally believed that the theme of this workshop is distinctive. Based on the urgent need for earthquake mitigation in slope engineering, the workshop systematically summarized the existing problems in the seismic research of slope engineering, the latest research results and engineering practices, and pointed out the direction of future development for the research and practice of seismic design and evaluation of slope engineering. It is of great value to improve the level of seismic design of slope engineering and the ability to prevent and reduce landslides triggered by the earthquake. The Shanghai Declaration not only embodies the

Fig. 2 Keynote lectures

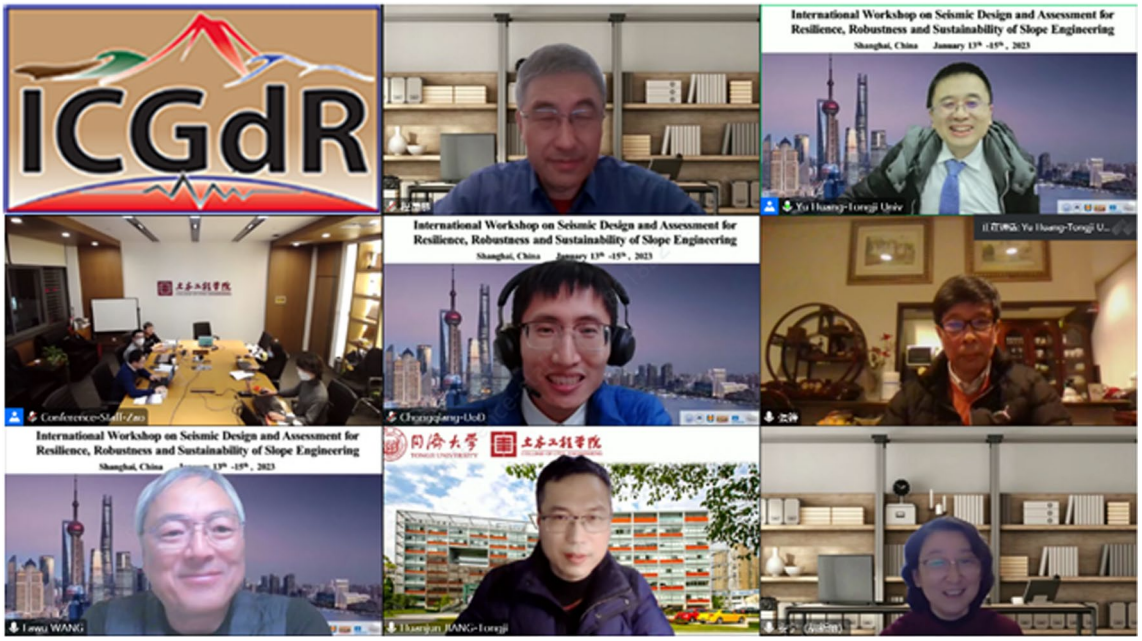

Fig. 3 Group photo of some representatives of the ICGdR-TC1

academic achievements of this international workshop but also expresses the future vision and consensus of developing resilient disaster prevention and reduction of global slope engineering, which is of great significance for improving the prevention and control of major engineering geological disasters.

Appendix: Resolution on slope engineering

For immediate release
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Shanghai declaration on the seismic resilience, robustness, and sustainability of slope engineering

By 2030: Slope engineering long-term monitoring system, Slope engineering seismic resilience assessment system and early warning platform; Ecological slope engineering resilience enhancement design.

Nearing the conclusion of a sometimes-fractious 3-day meeting titled "International Workshop on Seismic Design and Assessment for Resilience, Robustness, and Sustainability of Slope Engineering", experts of *TC1: Seismic Performance-based Design for Resilient and Sustainable Slope Engineering* of ICGdR agreed on a package of measures deemed critical to addressing the seismic resilience, robustness and sustainability of slope engineering.

The TC1 Experts Committee meeting hosted by Tongji University and jointly supported by ICGdR, adopted the following "Shanghai Declaration on the Seismic Resilience, Robustness and Sustainability of Slope Engineering" (SD-SRRSS), including five cruxes and 8 targets for achievement by 2030.

The five overarching cruxes

- Importance of continuous monitoring and seismic resilience for slopes is emphasized.
- Rational seismic design for ecological slopes should be carried out to realize sustainable developments of human society and nature with harmony.
- Researchers on repair and reinforcement technologies for existing slopes aiming for seismic sustainability should be strengthened ceaselessly.
- Technologies of rapid recovery of environment and optimized cost/performance design for post-earthquake slopes are urgently needed.
- Effective and executable communication and cooperation among relevant government sectors, private/state-owned enterprises and the people in seismic planning, design, construction, maintenance and management of slopes should be established and strengthened.

The targets for 2030

- Establish a complete slope monitoring system. Long-term terrain monitoring is realized through the combination of satellite, radar and ground 3D laser scanning. Combined with geophysical monitoring methods, the internal cracks and movement of rock and soil mass can be identified accurately and timely.
- Form a early warning platform and a complete seismic resilience assessment system for slopes, equipped with field monitoring technologies.
- Strengthen the researches on seismic resilience enhancement design for ecological slopes. By enhancing in-situ and laboratory tests both in fundamental research and seismic design, the resilience enhancement of ecological slopes and optimized combination with traditional structure in design can be expected.
- Research and development on post-earthquake repair and reinforcement technologies for existing slopes are strongly recommended, relevant patents are particularly appreciated, e.g., real-time monitoring platform.
- Clarify spatiotemporal distribution of disasters and their impacts on transportation system and water supply network to form a comprehensive and executable regional seismic resilience assessment method.
- Enhance cooperation between government sectors and enterprises to form a sound post-disaster emergency response strategy to carry out a systematic disaster early warning training for people in mountainous areas with 100% publicity. Meanwhile, best post-disaster recovery strategy considering socio-economic impact is strongly persecuted.
- Applications and demonstrations of relevant technologies for seismic resilience slope are recommended to be carried out in typical mountainous landslide areas world widely, through field practices, long-term monitoring and assessment, applicable assessment technology for seismic resilience enhancement effect, with optimum combination of traditional structure and ecological technology, is realized.

In addition to the SD-SRRSS, the meeting discussed the draft resolution of Seismic Design and Assessment Standard for Resilience, Robustness and Sustainability of Slope Engineering.

The TC1 Expert Committee will continue this work and release the future trend and progress reports. The purpose of this work and initiative is to effectively realize the construction of seismic resilience of slope engineering and effective disaster prevention and mitigation. At the same time, we actively absorb the experience and suggestions of experts and scholars from all over the world, and sincerely invite more colleagues to join us.

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Author contributions
WM, YW, CZ and ZH wrote the manuscript, YH and FW refined it. All authors read and approved the final manuscript.

Declarations

Competing interests
The authors declare that they have no competing interests.

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