frontiers | Frontiers in Earth Science

TYPE Editorial
PUBLISHED 16 December 2022
DOI 10.3389/feart.2022.1118991

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OPEN ACCESS

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SPECIALTY SECTION
This article was submitted to Geohazards and Georisks, a section of the journal Frontiers in Earth Science

RECEIVED 08 December 2022
ACCEPTED 09 December 2022
PUBLISHED 16 December 2022

CITATION
Xie M, Du Y, Jiang Y, Li B, Chicas SD and Ding J (2022), Editorial: Rock landslide risk assessment, stability analysis and monitoring for the development of early warning systems and reinforcement measures.
Front. Earth Sci. 10:1118991.
doi: 10.3389/feart.2022.1118991

Editorial: Rock landslide risk assessment, stability analysis and monitoring for the development of early warning systems and reinforcement measures

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KEYWORDS

rock landslide, unstable rock mass, early identification, warning technology, stability analysis, reinforcement measures

Editorial on the Research Topic
Rock landslide risk asssessment, stability analysis and monitoring for the development of early warning systems and reinforcement measures

Introduction

Rock landslide is one of the common geological disasters in the world, characterized by complex causes, wide distribution, strong concealment and suddenness, which result in great harm to human life and property (Corominas et al., 2005; Perkins, 2012; Ferrari et al., 2016). Yet, the early identification and warning technology of rock landslides have been difficult to effectively achieve. For instance, in China over 15,734 rock landslides occurred from 2011–2020, which caused approximately 4,394 casualties (Sreelakshmi et al., 2022). Therefore, it has important theoretical significance and application value to carry out a risk assessment and stability analysis for rock landslides, realize its early warning and implement effective control measures.

Based on research on the causal mechanism and early warning of rock landslides or collapse, it was concluded that the quantitative identification and fuzzy evaluation of rock bridges are the main controlling factors of these disasters (Du et al., 2021a). This innovative concepts in conjunction with technology have been applied in the identification of dangerous rocks, achieving remarkable results (Du et al., 2021b;

Chen et al., 2021; Huo et al., 2021; Du and Xie, 2022). However, there are still many deficiencies in the quantitative identification of rock landslides, real-time stability evaluation, and monitoring indicators that can be applied in the field. Recently, new monitoring technologies, theoretical models of instability and multi-source monitoring indicators provide new opportunities for early identification, monitoring and early warning of rock landslides (Colombero et al., 2018; Francesco et al., 2018; Jan et al., 2018; Jia et al., 2019; Bolla and Paronuzzi, 2020; Du et al., 2020; Gebremedhin et al., 2020). This Research Topic aims to present the latest risk assessment methods for identifying dangerous rocks, dynamic stability assessment techniques, early monitoring and warning systems, and reinforcement measures.

Identification of unstable rock masses

Unstable rock is a rock in a state of instability, which is one of the common types of the hidden danger points of geological hazards in hilly areas (Skrzypczak et al., 2021). Exfoliation of rock deteriorates cliffs through the formation and subsequent opening of fractures, which in turn can lead to potentially hazardous rockfalls. Although, a number of mechanisms are known to trigger rockfalls, many rockfalls occur during periods when likely triggers such as precipitation, seismic activity and freezing conditions are absent (Collins and Stock, 2016). The quantitative identification of unstable rock mass is the premise of rock mass monitoring and early warning. Due to many difficulties in rock bridge damage identification and rock mass dynamic stability evaluation, it is still impossible to objectively and accurately identify high-risk dangerous rock mass from the mechanical point of view at this stage.

In this Research Topic, we systematically carried out research on the rapid identification technology, method and discrimination system of unstable rock mass. By monitoring the dynamic characteristic parameters of the structure (such as natural vibration frequency), Jia et al. carried out research on the quantitative identification test of unstable rock mass. Firstly, through theoretical derivation and experimental verification, they established the quantitative relationship between rock mass, foundation reaction coefficient, rock burial depth and horizontal natural vibration frequency. The combination of the research results and the limit equilibrium model can realize the stability evaluation of the unstable rock based on the natural vibration frequency, and the safety factor can be monitored. Secondly, they present a dynamic characteristic model of rock tilting and identify the quantitative and qualitative relationship between dynamic characteristic parameters and the bonded area of the structural plane, which can be used to evaluate the damage degree of the structural surface of the overturned dangerous rock.

Although, there are many technical means for rapid identification of unstable rock mass, there are still some deficiencies in the quantitative identification of unstable rock mass from the aspect of mechanical indicators. Through triaxial compression tests on rock specimens with different bedding angles under different confining pressures, Zhang et al. studied the fracture characteristics and strength criteria of layered sandstone. Luo et al. comprehensively analyzed the influence of filling degree and shape fluctuation degree on the normal deformation characteristics of filling rock joints. Based on the multi boundary blasting theory, Shi et al. determined the theoretical value of the critical damage width of rock wall demolition blasting. On the basis of predecessors, Luo et al. conducted shear strength tests on weak intercalated rock joints with different filling degrees and water content under multi-stage normal stress. These studies provide theoretical reference for rapid quantitative identification of dangerous rock mass.

Dynamic stability assessment

Generally speaking, the dynamic stability evaluation technology of rock mass is the basis for effective implementation of monitoring and early warning. The whole process of rock mass from stability to collapse is also accompanied by real-time degradation of strength. The occurrence and development of damage and fracture of the main structural plane is the key to the study of collapse disaster mechanism and early warning prevention (Chen et al., 2015; Du et al., 2019a). Therefore, the identification and dynamic monitoring of rock bridge damage is one of the key problems to be solved in the early warning of rock collapse disaster.

Freeze-thaw cycles can heavily damage the internal structures of rocks. To explore damage evolution in granite in a freeze-thaw environment, Li et al. took a granite specimen of Linzhi area, Tibet as the research object, and analyzed the ro ck freezing and thawing damage by combining computed tomography scanning and three-dimensional visualization. Ai et al. introduced the strain-softening model and the vibration deterioration model to express the attenuation law of rock strength parameters, making the slope stability evaluation results more accurate and reliable. Song et al. put forward a mesh free particle approach named smoothed particle hydrodynamics method and improved the damage and failure process of rock slope to better describe the mechanism of brittle failure of rock slope.

At present, mature stability analysis methods for rock landslides have been developed and applied in engineering practice. Zhao et al. put forward and verified the effectiveness of limit equilibrium method in slope stability analysis of Tanjianshan Gold Mine. Based on GIS, Yu et al. established a three-dimensional limit equilibrium model for slope stability analysis, which provides a theoretical basis for the establishment of three-dimensional symmetric slope limit equilibrium method. Xu et al. proposes a method to determine the stability stage of creeping landslides as per their displacement characteristics. Based on this, a stability stage criterion method for landslide is formed.

Early monitoring and warning systems

Rock mass is an extremely complex structure. Its failure is not only controlled by two major internal control factors, but also affected by a variety of external disaster causing factors. Therefore, only by collecting more information on disaster causing factors through a variety of new monitoring technologies can the early warning and prevention of collapse disasters be effectively realized (Du et al., 2019b). Compared with so many information and data requirements, the existing monitoring technologies that can be used in practical projects are still relatively simple. The results in many technical problems in obtaining key information of internal disasters in rock mass, such as internal fractures of rock mass, rock bridge penetration rate, *etc.* Based on the critical deceleration theory, Tang et al. proposed that the CSD index can be used as a monitoring and early warning for the stability of field geotechnical engineering. Jin et al. applied the *in situ* stress measurement technology for the long-term monitoring of induced stress in slope engineering, and proposed a dual temperature compensation circuit and experimental calibration technology to improve the measurement accuracy. Jiang et al. proposed a new prediction model combining variable selection, sparrow search algorithm, and deep extreme learning machine. Minglei et al. summarized the typical deformation and failure modes of the tunnel, providing technical support for identifying landslide types through tunnel deformation characteristics in practical engineering applications.

Rock mass collapse is usually the dynamic failure caused by the continuous reduction of the bonding degree between rock mass and its slope. In this changing process, high-precision stress and strain monitoring and corresponding environmental parameter monitoring have certain effect in identifying collapse (Zhao et al., 2022). Based on this concept, Na et al. investigated mechanical creep characteristics and fracture evolution processes in rock masses with different fracture angles, lengths, and rock bridge dip angles. Zhang et al. investigated the creep behaviour of deep soft rocks and siltstone-like materials subjected to different unloading confining pressures coupled with a high stress field and seepage. All these provide a theoretical basis for the study of creep fracture law of rock mass and warning system of rock collapse.

Reinforcement measures

For many years, emergency response and post-event construction of structural measures were the main components of natural hazard management. In the past decades, an integrated risk management approach (IRM) emphasizing risk rather than hazards has been developed (Blaikie et al., 2004). IRM involves three main components (Christine et al., 2017): 1) Preparedness for a natural hazard event. 2) Response to an event. 3) Recovery after an event includes event analysis and permanent reconstruction. In this Research Topic, Jiaxing et al. proposed a set of building reinforcement and community elasticity enhancement methods that can resist slope deformation. In addition, a three-level disaster emergency setting system has been established in the urban area around the open-pit mine, and a disaster prevention and disaster resistance enhancement strategy has been established in the communities around the slope, so as to promote sustainable urban development.

In terms of rock landslide prevention and management, Du et al. introduced the characteristics, application, research methods and practical cases of anchor bolts, and looked forward to their application prospects in slope engineering. Chen et al. studied the reinforcement effect of bolts with negative Poisson's ratio on rocks and believed that this would be one of the development directions of bolt materials in the future. Yang et al. use phosphogypsum to prepare cementitious materials for backfilling the goaf, which provides a practical reference for the treatment of landslides. Guangming et al. explored the law of stratum collapse and surface settlement caused by the boulder in the process of tunnel excavation, which provided a theoretical basis for the protection of rock collapse.

Author contributions

MX: Conceptualization, and Writing—Review and Editing; YD: Conceptualization, Data Curation, Writing—Original Draft, Writing—Review and Editing and Funding acquisition; YJ: Writing—Review and Editing; BL: Writing—Review and Editing; SDC: Writing—Review and Editing; JD: Data Curation, Writing—Original Draft and Writing —Review and Editing.

Acknowledgments

The authors gratefully acknowledge the financial support from the National Key Research and Development Project of China (2018YFE0101100), National Natural Science Foundation of China (41702371), Project Supported by State Key Laboratory of Earth Surface Processes and Resource Ecology (2022-KF-01), and State Key Laboratory for GeoMechanics and Deep Underground Engineering, China University of Mining and Technology, Beijing (SKLGDUEK2130).

Conflict of interest

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