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Editorial: Evolution mechanism and control method of engineering disasters under complex environment

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Editorial on the Research Topic
Evolution mechanism and control method of engineering disasters under complex environment

Introduction

Against the backdrop of expanding resource development and the utilization of underground spaces, engineering disasters (such as landslides, tunnel collapses, earthquakes, debris flows, and urban infrastructure failures) have occurred frequently, resulting in substantial economic losses and casualties. Complex environmental factors, including weak or unstable geological structures, hydraulic and atmospheric pressure effects, heavy rainfall and water level fluctuations, fluid-solid coupling, earthquakes, and external dynamic disturbances, significantly impact the strength, deformation, and stability of geotechnical materials (Han et al., 2023), thereby increasing the risk of disasters such as landslides and tunnel collapses (Liu et al., 2024; Han et al., 2018). Consequently, investigating and understanding the evolution mechanisms of engineering disasters in complex environments and developing effective disaster control methods have become critical tasks in the engineering community.

To promote research progress in disaster prevention and control and to foster communication among peers, we are honored to introduce the Research Topic, "Evolution Mechanism and Control Method of Engineering Disasters Under Complex Environment." This Research Topic aims to gather cutting-edge research findings, novel methods, case studies, and review articles, with a particular focus on studies related to disaster control methods and failure evolution mechanisms. The Research Topic has received widespread attention and numerous submissions. The project has now concluded, with a total of 29 published papers covering the analysis of disaster evolution mechanisms, the development of control technologies, and numerical simulation methods. The research emphasis includes complex disaster scenarios such as landslides, tunnel collapses, and earthquakes. This Research Topic provides crucial support for understanding and mitigating engineering disasters in complex environments, laying a solid foundation for advancements in disaster prevention and control theories and practices.

Mechanical properties and failure mechanisms of rock masses

In complex environments, the study of the mechanical properties and failure mechanisms of rock masses is a key Research Topic in predicting engineering disasters. This research not only helps deepen our understanding of how rock materials behave under extreme conditions but also provides crucial scientific support for the safe design of engineering projects, disaster prevention, and risk management.

Zhou et al. conducted numerical analysis using the corner correlation method, systematically revealing the dynamic evolution process of rocks under impact loads. This study offers theoretical support for assessing the stability and safety of rock masses under conditions such as mining blasts and earthquakes. Jin et al. investigated the significant impact of high temperatures on the mechanical properties of sandstone, discovering that the strength and deformation behavior of sandstone change markedly under thermal conditions. This provides valuable data and guidance for geothermal energy extraction, post-fire building assessments, and other engineering projects in high-temperature environments.

In the research on heterogeneous granite, Chen et al. analyzed the correlation between macro and micro cracks, offering new insights into predicting rock mass fracture behavior. Their work is significant for preventing and addressing potential fractures and landslide risks in rock masses. Sun et al. studied the mechanical behavior of sandy dolomite tunnels under complex stress conditions and proposed analytical solutions that provide scientific guidance for the design and construction of tunnel projects.

Zhao et al. conducted an in-depth analysis of the mechanical behavior of steep rock slopes in cold regions under long-term freeze-thaw conditions. By comprehensively considering seasonal and diurnal temperature variations as well as the hydrogeological conditions of the mining area, they explored the evolution of frost heave forces under the combined influence of multiple factors, providing crucial insights for the design, construction, and operation of related engineering projects. Shao et al. (2023) examined the relationship between the material composition, pore microstructure, and macro mechanical properties of 3D-printed (3DP) rocks. This research provides advanced technical support for simulating the characteristics of natural rocks. The method allows for more precise and cost-effective rock mechanics experiments in the laboratory, reducing the complexity of field tests and promoting refined rock mechanics research.

These studies lay a solid foundation for understanding the mechanical properties and failure mechanisms of rocks under extreme conditions, providing essential technical support for disaster prevention and control in engineering projects.

Geological disasters: landslides, debris flows, and earthquakes

Geological disasters, such as landslides, debris flows, and earthquakes, pose significant challenges to engineering safety, especially under complex geological conditions. Studies have shown that these disasters are often driven by a combination of environmental and human factors, resulting in extensive and far-reaching damage.

By analyzing the characteristics and geological causes of deep-seated landslides in tuff formations, Jia et al. conducted a comprehensive analysis of the combined effects of earthquakes and rainfall, revealing how these two natural factors jointly impact slope stability, ultimately leading to landslide disasters. This research emphasizes the importance of understanding multi-hazard interactions and provides new perspectives for disaster risk management. Xue et al. provided valuable insights into the mechanisms of landslide occurrences in the region. This research not only deepened our understanding of the conditions under which landslides occur but also laid a theoretical foundation for future disaster prevention strategies.

Zhang et al. discovered that during coal seam mining, the destruction of the overburden of shallow coal seams and pressure changes directly weaken the stability of the surrounding soil, significantly increasing the risk of ground subsidence and landslides. These findings are crucial for environmental impact assessments of mining projects and the protection of regional geological stability. Zou et al. investigated the mechanisms of ground subsidence and crack expansion caused by multi-seam mining, providing scientific evidence for assessing the long-term environmental impacts of mining activities. Li et al. focused on the Ruihai Gold Mine, assessing the severity of rock bursts and proposing mitigation strategies. Through an in-depth analysis of rock burst characteristics, they provided guidance for enhancing mine safety management and reducing potential disaster risks.

Zhao et al. studied the impact of seismic activity on columnar jointed basalt, uncovering how earthquakes alter fault stability and increase the likelihood of landslides or rock mass instability. This study offers critical references for designing safer geological engineering projects. Zhang et al. further explored the characteristics of deep fractures and their impact on the destruction and displacement of overlying layers, offering new insights into understanding fault activity. The evolution of deep fractures is essential for predicting surface changes and developing effective disaster response strategies.

These studies not only advance theoretical knowledge but also offer practical support for developing strategies to prevent and respond to engineering disasters, driving further progress in the field of geological disaster prevention and control.

Tunnel collapse and underground space safety

In the study of tunnel collapses and underground space safety, multiple factors collectively influence the stability and safety of tunnel structures. Research has shown that the combination of complex geological conditions, high ground stress, water inrush risks, and external dynamic loads often leads to significant safety hazards in tunnel engineering. To address these Research Topic, scholars have conducted extensive in-depth research and proposed various innovative solutions and control strategies.

Zheng et al. explored the failure mechanisms and dynamic control measures for tunnels located in tectonic fracture zones under high ground stress. Their research provided a detailed analysis of how crack development and stress concentration affect tunnel stability, revealing the main causes of tunnel instability in high-stress environments. They also proposed feasible dynamic control methods, offering scientific support to enhance the safety of tunnel projects in such conditions. Kou et al. conducted a stability analysis of long-serving double-arched tunnels, paying particular attention to the safety risks associated with structural decommissioning. Their findings offer critical theoretical insights for evaluating the stability of aging tunnels and formulating decommissioning or maintenance plans.

Zhao et al. focused on the impact of blast loads on the mechanical performance of U-shaped steel support structures, discovering significant changes in their mechanical properties under explosive impact. This research provides a solid scientific foundation for designing support structures that are resistant to both earthquakes and blasts. Chen et al. developed a water inflow prediction model for mountain tunnels and conducted a comprehensive assessment of surrounding rock stability. Their research offers technical support for effectively managing water inrush risks in complex geological conditions.

Ji et al. proposed an innovative solution to address the problem of mud cake formation during shield tunneling. By employing high-pressure water jet cutting technology, they successfully reduced the impact of mud cake on tunneling efficiency, significantly improving the efficiency and safety of shield construction. Liang et al. studied the consolidation effects of soil-pipeline interaction during tunnel excavation and thoroughly investigated the impact of the excavation process on surrounding soil and underground pipelines.

Their research revealed the soil settlement and stress variations induced by tunnel excavation, providing scientific guidance for safeguarding the safety of underground infrastructure.

Urban infrastructure safety and structural stability

In the field of urban infrastructure safety and structural stability, researchers have conducted numerous in-depth studies focusing on the load-bearing capacity and overall stability of infrastructure. As engineering environments become increasingly complex, the importance of ensuring the safety and stability of urban facilities has become more prominent.

Zhang et al. conducted an in-depth analysis of the load-bearing characteristics of ultra-long, large-diameter piles in the Yellow River alluvial plain. By combining field experiments and numerical simulations, they investigated the effects of various pile lengths, diameters, and eccentric conditions on vertical ultimate bearing capacity, providing crucial data to support the application of piles under complex geological conditions in this area. Huang et al. studied the load-bearing behavior of post-grouted prestressed pipe piles. By utilizing finite element simulations and on-site static load tests, they analyzed the effectiveness of end-grouting techniques. The results showed that this technique significantly enhances the bearing capacity of pipe piles and reduces settlement, confirming its feasibility and reliability under complex karst conditions.

Liu et al. also conducted experiments considering excavation width, investigating the stress and deformation characteristics of foundation pits. Using 3D printing technology to create scale models, they analyzed the mechanical response patterns of support structures under different widths, providing theoretical and practical guidance for foundation pit design and construction. Pang et al. conducted experimental research on the load-bearing performance of mechanically stabilized earth walls, providing reliable empirical evidence. Their findings further refined construction standards for stabilized earth walls, ensuring structural safety in coastal and geologically complex areas.

Liu et al. proposed a new type of anti-floating prestressed compression anchor bolt. Through a combination of field pull-out tests and numerical analysis, they demonstrated its effectiveness in reinforcing underground structures against buoyancy. This research is particularly suitable for environments with frequent water level fluctuations and provides effective technical support for the safety management of underground spaces. Wang et al. conducted freeze-thaw and cyclic triaxial tests to experimentally reveal the evolution of cumulative plastic strain behavior in thawed subgrade soils. Based on stability theory, they established classification standards for different plastic deformation limits and developed a method to calculate critical dynamic stress, providing theoretical support for the long-term safety and sustainable design of subgrades.

These research findings collectively enhance the safety and reliability of urban infrastructure, offering scientific support for future engineering practices.

Disaster control and prevention

In the field of disaster control and prevention, as well as numerical simulation and monitoring technology, numerous research projects have provided important tools and methods to enhance engineering safety and risk management.

Wang et al. conducted an in-depth study on the mechanical properties of frozen pipes and the characteristics of acoustic emission signals. They examined how temperature changes affect the strength and toughness of pipeline materials, offering scientific guidance for infrastructure design in cold regions. Su et al. developed an innovative method for real-time monitoring and structural health assessment by analyzing the propagation characteristics of guided waves in concrete and damage identification techniques. This technology allows engineers to efficiently detect structural damage and take timely preventive measures, significantly enhancing the overall safety of buildings and infrastructure. Tian et al. designed and validated an embedded monitoring device for lateral friction resistance in foundations. By integrating sensor theory with field experiments, they provided a high-precision real-time monitoring tool for infrastructure stability. Their research addressed the limitations of traditional monitoring equipment, which often suffers from low precision and challenges in long-term application, ensuring the safety of infrastructure during both construction and operation.

Li et al. applied Bayesian estimation methods to predict the rock mass grades at tunnel faces, demonstrating the practical application of data-driven predictive approaches in geotechnical engineering. This study significantly improved the accuracy of rock mass grade predictions, making the construction process safer and more efficient, while providing essential decision-making support for construction in complex geological environments. Teng et al. explored optimized strategies for grouting treatment to prevent subsidence and collapse in underground mined-out areas. They studied the effective application of grouting techniques for foundation reinforcement, proposing more efficient grouting formulations and analyzing the impact of grouting pressure, flow rate, and material properties on reinforcement outcomes. This research provides practical solutions for the safe management of underground spaces.

These research findings offer solid technical support and theoretical foundations for disaster control and engineering safety management.

Conclusion and outlook

In complex environments, the study of the evolution mechanisms and control methods of engineering disasters is crucial. By conducting in-depth analyses of disasters such as landslides, tunnel collapses, and debris flows, we have gained a preliminary understanding of their triggering mechanisms and evolutionary processes. This has laid the foundation for improving engineering safety and disaster prevention capabilities.

In the future, research will advance toward more intelligent and precise directions. The application of machine learning technology (Zhang et al., 2023) will bring new possibilities for monitoring and predicting engineering disasters (Liu et al., 2024). By analyzing vast amounts of historical data, machine learning can effectively identify potential disaster patterns and improve the accuracy of early warning systems.

At the same time, large-deformation collapse simulation will become a critical research area. Traditional simulation methods often face limitations when dealing with complex nonlinear behaviors. Therefore, developing a new generation of numerical models, particularly those capable of capturing large deformations and multi-physics coupling effects, will help more accurately reflect the dynamic processes of disaster occurrences.

Moreover, we need to strengthen interdisciplinary collaboration, integrating research findings from geotechnical engineering, computational mechanics, machine learning, and environmental science. By combining these efforts, we aim to advance disaster prevention and control technologies in complex environments, achieving significant progress in ensuring engineering safety, reducing disaster risks, and promoting sustainable development and human safety.

Author contributions

JH: Conceptualization, Formal Analysis, Funding acquisition, Investigation, Writing–original draft, Writing–review and editing. HL: Methodology, Writing–original draft, Writing–review and editing. XB: Methodology, Supervision, Writing–original draft, Writing–review and editing. ZL: Writing–original draft, Writing–review and editing. J-JS: Writing–review and editing. PJ: Writing–review and editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author(s) declare that no Generative AI was used in the creation of this manuscript.

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