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Editorial

Mechanical Properties of Rocks under Complex Stress Conditions: Investigations Using Experimental and Numerical Methods

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1. Introduction

Rock engineering constructions are widely attested in energy mining, geothermal development, and underground energy storage projects. In these projects, rocks are maintained complex stress conditions, including thermal–hydro-mechanical (THM) conditions, hydraulic fracturing, liquid nitrogen freezing, blasting, etc. Investigations of the mechanical behaviors of rocks under complex conditions are essential for engineering modeling and design. This knowledge can advance our understanding of rock materials and enhance the safety and efficiency of rock engineering construction and operations. Therefore, in this Special Issue, entitled "Mechanical Properties of Rocks under Complex Stress Conditions", we gathered papers from scholars from all over the world aiming to resolve the challenges of rock mechanics. A total of 24 manuscripts were submitted to this Special Issue, and 14 papers were accepted for publication (i.e., a 58% acceptance rate).

2. Mechanical Properties of Rocks under Different Conditions

These 14 papers mainly focus on experimental studies on rock mechanical properties under the conditions of triaxial unloading, deep high stress, high temperature, and the freeze–thaw cycle. One paper, using the discrete element method, investigates the dynamic response of anti-dip bedding rock. Cui et al. [1] compared the fatigue activity of rock salt using continuous zero-stress fatigue tests and those structured by time intervals. The results indicated that residual stress can cause adjustments of the internal structural of rock salt on a mesoscopic scale. Zhang et al. [2] reported that the deterioration degree of granite increases as the temperature increases, and the cooling methods also have effects on the physical properties of the rock. Xu et al. [3] suggested that as freeze–thaw damage increases, the mechanical parameters (elastic modulus and peak stress) decrease, while the porosity increases. Zhou et al. [4] developed electro-hydraulic servo-point load equipment and investigated the influence of the loading rate on the axial stress distribution of rock. Zhang et al. [5] proposed a cluster microseism-based method to improve the prediction accuracy of mining earthquakes. Kuang et al. [6] investigated changes in the strength, ultrasonic characteristics, and crack distributions of granite after applying a laser beam under various irradiation conditions. The results indicated that the laser irradiation technique can efficiently identify fracture graphite. Fu et al. [7] proposed a method for expanding the rescue channel in a collapsed body, and the method was further verified using a model and numerical simulation tests. Zhou et al. [8] investigated the deterioration effect of liquid nitrogen on heated granite using experimental and theoretical methods and proposed a statistical damage constitutive model to describe the influence of this condition

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on rock mechanical properties. Bai et al. [9] conducted a series of triaxial compression tests on coal samples and discussed the dynamic failure characteristics and mechanism of coal bursts under different mining-induced stress disturbances. Zhang et al. [10] studied the influence of stress anisotropy on the petrophysical parameters of tight sandstone. Shi et al. [11] conducted triaxial drained shear, loading–unloading, and standard consolidation tests on sandy gravel specimens and obtained stiffness parameters of the hardening soil based on a model of a sandy gravel stratum. Duan et al. [12] conducted a series of triaxial unloading confining pressure tests to study the failure process of rock mass. The energy evolution and crack characteristic stress of the rock mass in the unloading process were discussed. Cai et al. [13] investigated the effect of methane adsorption on mechanical properties of coal through a large number of triaxial compression tests under different conditions. The results showed that the adsorption equilibrium pressure has a negative relationship with the compressive strength of coal. Finally, Ren et al. [14] developed a three-dimensional discrete-element numerical method for the dynamic analysis of rock slopes with different joint sets and found that the angle between the joint and slope can significantly influence the failure mode, permanent displacement, and stability of slopes.

3. Prospect

Although submissions to this Special Issue are now closed, more in-depth research related to rock mechanical characteristics is expected in the future. It can be predicted that more opportunities and challenges will present themselves as scholars continue to explore underground engineering. Therefore, more strategies should be developed to respond to challenges related to the experimental methods, equipment, materials, techniques and numerical models used for rock mechanical behavior investigation.

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References

1. Cui, Y.; Liu, C.; Qiao, N.; Qi, S.; Chen, X.; Zhu, P.; Feng, Y. Characteristics of Acoustic Emission Caused by Intermittent Fatigue of Rock Salt. *Appl. Sci.* **2022**, *12*, 5528. [CrossRef]
2. Zhang, J.-S.; Lu, Y.; Pang, J.-Y.; Bu, Y.-S. Experimental Study on Mechanical Properties of High Temperature Granite with Different Cooling Methods. *Appl. Sci.* **2022**, *12*, 5968. [CrossRef]
3. Xu, J.; Pu, H.; Sha, Z. Effect of Freeze-Thaw Damage on the Physical, Mechanical, and Acoustic Behavior of Sandstone in Urumqi. *Appl. Sci.* **2022**, *12*, 7870. [CrossRef]
4. Zhou, X.; Qiao, L.; Wu, F.; Wang, Z.; Chen, Y.; Wu, J. Research on Rock Strength Test Based on Electro-Hydraulic Servo Point Load Instrument. *Appl. Sci.* **2022**, *12*, 9763. [CrossRef]
5. Zhang, P.; Li, X.; Chen, J. Prediction Method for Mine Earthquake in Time Sequence Based on Clustering Analysis. *Appl. Sci.* **2022**, *12*, 11101. [CrossRef]
6. Kuang, L.; Sun, L.; Yu, D.; Wang, Y.; Chu, Z.; Darkwa, J. Experimental Investigation on Compressive Strength, Ultrasonic Characteristic and Cracks Distribution of Granite Rock Irradiated by a Moving Laser Beam. *Appl. Sci.* **2022**, *12*, 10681. [CrossRef]
7. Fu, Y.; Xie, K.; Xiao, F.; Liu, G.; Hou, Z.; Zhang, R. Motion Characteristics of Collapse Body during the Process of Expanding a Rescue Channel. *Appl. Sci.* **2022**, *12*, 11034. [CrossRef]
8. Zhou, C.; Gao, F.; Cai, C.; Zheng, W.; Huo, L. Mechanical Properties and Damage Evolution of Heated Granite Subjected to Liquid Nitrogen Cooling. *Appl. Sci.* **2022**, *12*, 10615. [CrossRef]
9. Bai, J.; Dou, L.; Li, X.; Cao, J.; Wang, K.; Chai, Y.; Kan, J. Mechanism of Coal Burst Triggered by Disturbing Mining-Induced Stress: An Experimental Investigation. *Appl. Sci.* **2022**, *12*, 10993. [CrossRef]
10. Zhang, H.; Xu, K.; Zhang, B.; Yin, G.; Wang, H.; Wang, Z.; Li, C.; Lai, S.; Qian, Z. Influence of Stress Anisotropy on Petrophysical Parameters of Deep and Ultradeep Tight Sandstone. *Appl. Sci.* **2022**, *12*, 11543. [CrossRef]
11. Shi, X.; Sun, J.; Qi, Y.; Zhu, X.; Zhang, X.; Liang, R.; Chen, H. Study on Stiffness Parameters of the Hardening Soil Model in Sandy Gravel Stratum. *Appl. Sci.* **2023**, *13*, 2710. [CrossRef]

12. Duan, Y.; Zhang, G.; Qin, T. Analysis of Crack-Characteristic Stress and Energy Characteristics of Sandstone under Triaxial Unloading Confining Pressure. *Appl. Sci.* **2023**, *13*, 2671. [CrossRef]
13. Cai, F.; Yin, J.; Feng, J. Effect of Methane Adsorption on Mechanical Performance of Coal. *Appl. Sci.* **2022**, *12*, 6597. [CrossRef]
14. Ren, Z.; Chen, C.; Sun, C.; Wang, Y. Dynamic Analysis of the Seismo-Dynamic Response of Anti-Dip Bedding Rock Slopes Using a Three-Dimensional Discrete-Element Method. *Appl. Sci.* **2022**, *12*, 4640. [CrossRef]