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Editorial

Energy Geotechnics and Geostructures

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Continuous global economic and population growth has driven the ever-increasing demand for energy. Meanwhile, public awareness regarding resource protection, climate change and sustainable development is an indispensable factor in responding to the global energy demand. In addition to efforts in exploring and producing more fossil fuels, greater attention should be paid to energy resources that are clean and sustainable but have been neglected for a long time. As differences in potential fields, such as temperature, elevation and hydraulics, commonly exist between engineering structures and geological bodies, their interface presents opportunities that have yet to be explored in energy supply, conversion, and storage. These opportunities have advantages of shallow depth, proximity to users and stability.

Energy geostructures refer to civil foundations or other buried geotechnical structures that are equipped with heat-transfer or other energy-exchange devices and facilities [1]; thus, they are able to exchange energy with geological bodies. Energy geostructures eliminate the construction of heat exchangers with a special purpose, thereby offering opportunities for recovering existing energy at a low cost. Most energy geostructures are dual-function engineering sub-structures for heat transfer and storage, aside from the original structural purpose [2], in the forms of integrating geothermal extraction with building foundations, including energy piles, walls and tunnels. However, more broadly, they also cover technologies, such as the utilization of abandoned underground mine space in energy storage, geological carbon utilization and storage, underground coal gasification, underground data center, and co-mining of minerals and geothermal resources. Energy geotechnics involves the use of geotechnical principles to understand and resolve engineering problems in exploration, recovery, exchange and storage of energy resources in the subsurface [3]. It focuses on the combined behaviors of natural soils and rocks and engineering structures in complex and extreme mechanical–hydraulic–thermal–geochemical coupling processes.

As the challenges in mitigating climate change and securing energy supply become urgent, energy geotechnics and energy geostructures have demonstrated great potential not only in improving traditional energy recovery and utilization but also in promoting and developing novel energy technologies. Interdisciplinary research involving the fields of geological engineering, civil engineering, mining engineering, and heat transfer and thermal engineering has advanced innovations in new materials for high heat conduction and storage capacity, new structural designs for efficient heat transfer, optimization of design and project management, new simulation technologies, smart monitoring systems, and others.

This Special Issue, entitled "Energy Geotechnics and Geostructures", includes seven articles, which themes cover investigation of constructing a pumped-storage power station in abandoned coal mine space [4], bearing characteristics of bolts [5], a mobile refrigeration system in underground mines [6], mitigation of thermal imbalance in energy storage rocks associated with ground-source heat pump operation [7], weighting procedure for geomechanical risk assessment [8], prevention and control of spontaneous combustion of remained coal in a roadway [9], and analysis and calculation of heat exchange capacity and thermal properties of buried pipes in a fractured rock mass [10]. The following is a brief summary of the content of each paper selected for publication in this Special Issue.

Lyv et al. [4] conducted a feasibility study on pumped-storage power stations by utilizing the spaces of an abandoned coal mine, while taking the natural conditions, mine conditions, safety conditions, and economic benefits into account. The authors presented a plan for the construction of a pumped-storage power station in the Shitai Mine in Anhui, China. Their research reveals that the proposed technology could bring in economic, ecological, and social benefits, including resource reuse, ecological restoration, and elimination of population resettlement. The technology also reduces the cost and construction period and improves the peak-load regulation and energy storage urgently needed for the development of power grid systems.

Zhang et al. [5] studied the mechanical properties and failure characteristics of a coal–rock combined anchor body under different pull-out rates using the pull-out test and theoretical analysis. The characteristics of the anchor and the bolt pull-out failure were examined, and the bearing characteristics and failure forms of the coal–rock combined anchor body were determined. The failure of the coal and rock mass occurs at different times and can be divided into three stages. This study provides a reference that can support bolt design and ground control of coal–rock roadways.

Li et al. [6] designed a mobile refrigeration system for high-temperature mining working face and carried out a field test in the Dahongshan Copper Mine, Yunnan Province, China. Based on the experimental conditions, the parameters of the mobile refrigeration system were further optimized. This research is of significance in providing new ideas and methods for the prevention and control of heat damage in deep and high-temperature metal mines.

Luo et al. [7] adopted laboratory experiments and numerical simulations to analyze the mechanism regarding how fracture water in a karst landscape influences the heat capacity and thermal imbalance of the energy storage rock mass. The results showed that the overall temperature fluctuation of the rock mass was reduced by the fracture water, but the impact of water flow was constrained in the proximity regions of the fractures and decreased obviously with distance. The authors suggested that heat exchange boreholes in fractured regions should share a greater load, or a denser placement should be adopted as the drilling technique, to take advantages of the higher heat-transfer capacity improved by water flow.

Aiming to develop a realistic weighting procedure to assess and compare various geomechanical parameters that pose a risk to the stability of mine openings, Mortazavi and Kuzembayev [8] used the sub-level stoping mining methods to test the developed weighting algorithm. Further, risk-prone geomechanical parameters for the chosen mining method were defined, and a weighting procedure was developed using the Fuzzy Analytic Hierarchy Process (FAHP) method, which is proven to be a reliable method for weighting geomechanical parameters and can be used as an input in any geomechanical risk assessment practice.

Zhang et al. [9] investigated the effects of normal mining period, a goaf-retaining roadway as a return air roadway, air leakage prevention, and nitrogen injection measures in goaf on the spontaneous combustion and distribution characteristics of flow, oxygen and temperature fields in goaf using numerical simulation. The temperature rise in goaf was attributed to the increases in permeability, air leakage and oxygen concentration. Additionally, the authors constructed a hierarchical prevention, control, and fire-extinguishing technology system of the goaf-retaining roadway.

Wang et al. [10] proposed and deduced a fast and low-cost method to calculate heat exchange capacity of buried pipes in a fractured rock mass based on fracture distribution characteristics. Taking an actual project in a carbonate rock area as an example, the borehole heat-transfer capacity was obtained and compared by two methods: in situ thermal response test and calculation based on outcrop fracture distribution characteristics. The reliability of the calculation method based on fracture distribution characteristics was verified as its results were basically consistent with those of the in situ thermal response test.

The papers mentioned above are representative examples published in this Special Issue. Many achievements have been made in the fields of construction and drilling technologies, advanced materials, economic analysis, and other related areas. It is crucial to develop more efficient, cleaner and low-cost technologies in geotechnics and geostructures. Since energy resources, storage potential and utilization technologies are strongly impacted by the natural characteristics of geological formations/layers, we encourage more research efforts on the quick and low-cost characterization of geological bodies, tailored evaluation and design methods, and operation strategies for complex geological conditions. This includes the use of advanced piping and backfill materials that compensate for some of the natural defaults of soils and rocks, and the combination of multiple renewable energy resources and corresponding dispatch and control algorithms. We believe that these technologies can greatly contribute to and advance the commercialization and popularization of energy geotechnics and geostructures.

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