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Editorial

Advances in Engineering Geology of Rocks and Rock Masses

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1. Aims and Content of the Special Issue

Slope instability phenomena are among the most hazardous natural events affecting our society, and therefore the physical–mechanical behavior of rock masses with reference to these is a relevant topic for engineering geological practice, as it conditions the realization and functionality of structures and infrastructures, as well as the quality of life and economy. The study of rocks at different scales is, therefore, a scientific subject deserving continuous implementation in terms of experiences, modeling, innovation and solutions.

The Special Issue "Advances in Engineering Geology of Rocks and Rock Masses" collects scientific and technical contributions addressing this topic with the aim of providing an overview of the state of the art, future perspectives and challenges by means of case studies, rockfall hazard and risk assessment methodological applications, mathematical models, numerical simulation and field operations. Six articles were published in the frame of this Special Issue. Their geographical provenance, in terms of authors' affiliation, derives from Austria (1 article), China (2 articles), Italy (1 article), Spain (1 article) and Pakistan–China (1 article). Topics span from the rock mass discontinuity key parameters characterization and measurement through novel approaches to the application of internationally acknowledged rockfall risk rating systems in modified versions, to the behavior of rock masses for excavation and bearing purposes.

2. Overview on Published Contributions

In the article entitled *A New Characterization Method for Rock Joint Roughness Considering the Mechanical Contribution of Each Asperity Order* [1], insights on the rock discontinuity characterization are provided with the aim of establishing a formula for the joint roughness characterization by considering the mechanical contribution of each asperity order. Laboratory shear tests were performed on sandstone samples crossed by joints affected by different roughness degrees and asperity orders. In particular, three types of joint specimens with different asperity orders (flat, the standard JRC profile, and the profile containing only waviness) were considered. The mechanical contributions of waviness and unevenness were studied, as well as the relationship between the mechanical contribution and the morphology contribution of waviness and unevenness. Achieved results showed that, as normal stress increases, the influence of the joint surface morphology on its shear strength gradually decreases, and the relationship between the mechanical contribution ratio and the statistical parameter ratio of the waviness and unevenness can be described by a power function. Finally, the authors provide a formula for the accurate characterization of the joint surface roughness and the evaluation of its shear strength.

The article *Semiautomated Statistical Discontinuity Analyses from Scanline Data of Fractured Rock Masses* [2] focuses on the determination of basic statistical discontinuity parameters through open-source high-level language. The proposed workflow provides a semiautomated statistical discontinuity analysis of raw scanline data for determining (a) the normal set spacing probability density distribution and the mean of individual discontinuity sets; (b) the mean linear frequency of sets; (c) the mean and the distribution of trace lengths of

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each set; and (d) the termination index. The study was based on the assumptions that the discontinuities are plane surfaces in 3D models and straight lines (traces) in 2D models, and that the discontinuities of a set are aligned in parallel for the normal spacing calculation. Despite these assumptions, and some limitations summarized in the paper, the presented workflow represents a tool for objective data acquisition and analysis compared to the conventional sampling in the field.

The paper *Modified "Rockfall Hazard Rating System for Pakistan (RHRSP)": An Application for Hazard and Risk Assessment along the Karakoram Highway, Northwest Pakistan* [3] examines the application of the internationally acknowledged Rockfall Hazard Rating System (RHRS) [4] in a version specifically modified to take into account some peculiarities characterizing Pakistan's roads, where the animal activity is acknowledged as a rockfall triggering cause. Grazing altitude, road shoulder width, animal tracks and slope steepness were chosen as parameters to quantify animal activity. The modified rating system was tested along the Karakoram Highway for hazard mapping purposes, supported by rockfall inventory, rock mass surveys and kinematic analysis. The results of the case study showed that roads characterized by narrow width, limited shoulder width and insufficient protection measures returned the highest hazard conditions.

In the article *Interaction between Rockfalls and Vehicles Studied for Speed Limit Zonation along Mountainous Roads* [5], the RHRS, modified for Italian road standards [6], was applied along a mountainous road segment with a specific focus on traffic and vehicle speed limit zonation. The authors iterated the risk estimation by considering five scenarios assuming different vehicle speed limits posted along the road (10 to 50 km/h), with the aim of shedding light on the implication of this parameter when dealing with rockfalls along linear infrastructures. Results show that the rockfall risk increases as the vehicle speed increases, although for very low speeds (10 and 20 km/h) no significant difference was highlighted. Maximum incidence was observed at low-visibility segments (bends). This suggests that RHRS can also be used as a supporting tool for the estimation of the most suitable speed limit to post along roads in relation to the rockfall threat.

The article *Bearing Capacity of Footings on Rock Masses Using Flow Laws* [7] is focused on the study of the influence of the dilatancy angle on the bearing capacity of shallow foundations on rock masses through a model based on a numerical analysis carried out through the finite difference method. The authors aimed to estimate the upper and lower limits of the bearing capacity in terms of the function of the flow law by introducing a correction factor to take into account the decrease in the bearing capacity due to the adoption of the non-associative flow rule, with null dilatancy under the assumptions of a weightless rock mass. Achieved results show that the rock parameters affecting the proposed models are the rock type, the uniaxial compressive strength (UCS) and the Geological Strength Index (GSI). This latter is the main determining factor; in fact, the influence of dilatancy is relevant for low-strength rock masses, offering a low bearing capacity. For very low quality rock masses the adoption of null dilatancy is recommended, according to Hoek and Brown [8].

The paper *Optimization of Pre-Splitting Blasting Hole Network Parameters and Engineering Applications in Open Pit Mine* [9] was aimed at modelling different pore sizes and hole spacing to optimize the parameters of a pre-splitting blasting hole network at an open-pit mine in Inner Mongolia. The authors used numerical simulation software to model the stress propagation, strain change, and the evolution of main cracks and wing cracks between holes, achieving a formula to calculate the optimal hole diameter and hole spacing. They found that a 130mm diameter borehole has the fastest energy attenuation rate, and that for smaller apertures the effective tensile stress shows a continuous attenuation trend as the aperture spacing is increased.

3. Discussion and Perspectives

The scientific and technical content of this Special Issue is rich with hints that can surely be considered an advance in the engineering geology of rocks and rock masses.

The use of novel approaches for the measurement and evaluation of key discontinuity parameters [1,2], whose relevance in the rock mass behavior has long been established (e.g., [10,11]), represents a step towards the progressive automation of rock mass survey and mechanical characterization.

Similarly, the adaptation of semi-quantitative rating systems to specific requirements represents a practice aimed at a global acknowledgement of conventional procedures for rockfall risk estimation, which had initially been developed for local standards. For instance, animal activity, already recognized as a rockfall predisposing/triggering cause (e.g., [12,13]), has been included as a rated parameter to assess the risk along roads crossing slopes affected by animal grazing [3]. On the other hand, based on the established utility of rockfall hazard and risk assessment procedures along roads for planning purposes (e.g., [14]), the use of a semi-quantitative system to evaluate the most suitable speed limit for vehicles [5] suggests new perspectives looking towards further potential applications, thus widening the utility of already established methodologies.

A focus on the rock mass behavior has been addressed by adopting the flow law as a hypothesis in the method chosen for the calculation of bearing capacity [7]. This latter, indeed, is commonly calculated from the Mohr–Coulomb parameters (cohesion and friction angle), which are derived from the non-linear Hoek and Brown failure criterion [8]. Starting from this point, new insights have been brought on the influence of intact rock and rock mass properties on the rock mass bearing capacity.

Similarly, numerical modelling proved useful in choosing the most suitable diameter borehole and spacing for pre-splitting blasting operations [9], paving the way to future applications of advanced test and computer technologies.

Achieved and summarized results allow the conclusion that the engineering geological applications to rock mechanics represents a cradle of knowledge, purposes and ideas for advancing technological progress, the results of which would positively impact society and the economy. For this reason, the further development of new challenges and perspectives has to be encouraged and supported in the frame of a continuous modernization of applications and technologies.

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