Simulation of failure mechanisms around underground coal mine openings using discrete element modeling

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Roof failure has always been a major concern in underground coal mine roadways. Understanding the failure mechanism of roadway roofs is important for improving the safety of underground coal mines and reducing economic loss. In this research, new numerical modelling techniques are developed in an attempt to overcome the limitations of traditional approaches for modelling a realistic rock failure. The research primarily focuses on the investigation of typical failure mechanisms experienced in underground coal mines using numerical approaches.

A numerical modelling methodology named UDEC Trigon in 2D and 3DEC Trigon in 3D and based on a discrete element framework is developed to model rock mass behaviour, with a particular focus on the damage process including generation and propagation of fractures, and heavy dilation in the post-peak failure stage. The methodology is first used to investigate brittle failure mechanisms at the laboratory scale. A proposed damage parameter is introduced which allows the evaluation of simulated rock damage in a more quantitative manner.

The UDEC Trigon approach is subsequently used at the field scale to investigate typical failure mechanisms experienced in underground coal mine roadways. The shear failure mechanism in roadway roofs is investigated using a conceptual roadway created using UDEC Trigon, ELFEN and PFC2D, respectively. The effects of rock bolting on suppressing shear failure are evaluated using numerical simulation. Cutter roof failure, which is a three-dimensional roadway rock failure mechanism, is studied using both PFC3D and 3DEC Trigon. A squeezing roadway caused by high mining-induced stress at the Zhangcun Coal Mine is studied using UDEC Trigon. A conceptual roadway model is created using UDEC Trigon to simulate squeezing failure due to time-dependent strength degradation of moisture sensitive rocks. In addition, the UDEC Trigon approach is used to simulate the progressive caving process of the strata above the mined-out area of a longwall panel due to extraction of a coal seam. A further demonstration of the potential of UDEC Trigon in capturing roadway failure is presented as a case study of a roadway driven adjacent to unstable goaf in the Wuyang Coal Mine. The insights gained from this research provide an improved understanding of typical failure mechanisms in underground coal mine roadways, guiding the design of panel layout and roadway support. The 3DEC Trigon method provides an alternative for simulating rock damage under real 3D conditions.