nation, undercut structure, cave footprint and regulators on the cave airflow resistance. Both the experimental and CFD simulation results demonstrated that the increment of porosity and particle size in the caved materials increases the area available for flow within the cave (decreased airflow resistance) and increased airflow distribution percentage through the cave system under a given regulator combination. The shrinkage/reduction of cave footprint decreases the area available for flow within the cave (increased cave airflow resistance) significantly. The undercut drifts' opening decreased the cave airflow resistance. The use of regulators increased the fan head pressure, decreased the overall airflow rate, and changed the distribution of airflow rates through the cave system and extraction drifts. The increase of airflow rate through the system is favorable for gas dilution regardless of the source locations; while the regulated airflow system might deteriorate gas dilution performance especially when the source is located in the extraction level.

At an operating mine, the particle size of caved materials, distribution of rock size exploited from drawpoints, and cave footprint alternation should be monitored as these are the bases for porosity change and cave airflow resistance. The study shows that the gas concentration in extraction drifts can be above the desired limit. The gas concentration in the extraction drifts should be monitored and correlated with the characteristics of ore and waste material within the cave. Ventilation should be adjusted according to the dynamics of the caving process and various locations of gas sources. The findings from this study provide useful information for the optimization of a block cave mine ventilation system. ■

Selected references

1. Pan Y, Jha A, Tukkaraja P (2018) An Investigation of the effects of particle size, porosity, and cave size on the airflow resistance of a block/panel cave. Proceedings of the 11th International Mine Ventilation Congress
2. Bhargava R et al. (2021) Airflow characteristic curves for a mature block cave mine. CRC Press: London. 56–64
3. Loring DM et al. (2015) A discussion of the automated ventilation systems at the Henderson mine. In 15th North American Mine Ventilation Symposium. Virginia, USA

Topical Collection on Ground Control in Mining

Assessment of floor heave associated with bumps in a longwall mine using the discrete element method

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Special Extended Abstract

The floor-heave and no-floor-heave phenomena at a western U.S. coal mine could not be properly simulated in numerical models using conventional shear-dominant failure criteria. Although the previous numerical study using FLAC3D very reasonably demonstrated these phenomena, 3DEC modeling in conjunction with the discrete fracture network (DFN) technique was performed to better understand the true behavior of floor heave associated with underground mining in an anisotropic stress field. As a result, the latter models predicted floor heave that agreed with relative amounts of observed heave from each gateroad system, but the cause of heave was mainly related to the degree of anisotropy instead of the size of the pillar.

Introduction

Researchers from the National Institute for Occupational Safety and Health (NIOSH) observed floor heave at a western U.S. coal mine where pillar width in a three-entry gateroad system was 52 m, whereas no perceptible floor heave occurred where the pillar width in the gateroads was 22 m, as shown in Fig. 1. The floor heave most often occurred soon after development, and additional stress resulting from panel mining only increased the amount of floor heave. This area of irregular cleat orientation is of particular interest because a bump later occurred with damage that included much of this area with variable cleats.

Methods

The two main goals of this study are: (1) to construct different levels of anisotropy and different cleat systems with DFNs in 3DEC [1] models and (2) to test these models to see if they can replicate the floor-heave and no-floor-heave phenomena observed and to explain the influence of anisotropy and cleat development on the failure mechanisms in gateroad systems of different pillar widths.

In this study, the DFN is used to explicitly create the different levels of anisotropy and development of cleat sets in the coal seam of each gateroad system. A statistical parameter is used to realize the DFNs. As a result, the poorly cleated coal seam with oblique angles from horizontal — where horizontal is the plane that is parallel to the simulated coal seam — is generated in the wide pillar system, and the well-cleated coal seam with subparallel angles from horizontal is generated in the narrow pillar system, respectively, as per observations.

Ultimately, the 3DEC-DFN analyses replicate the floor-heave and no-floor-heave phenomena previously simulated using FLAC3D models [2] and explains the influence of anisotropy and cleat development on the failure mechanism in each gateroad system.

Results and discussion

Greater anisotropy for the wide pillar system was achieved using explicit DFNs, with the wide pillar system having a greater range of orientation and smaller spacing and persistence than in the narrow pillar system, where DFNs had a smaller range of orientation that was subhorizontal or subvertical as per the previous study [2].

To create the DFNs representing the oblique included angles, the Fisher constant, K, was determined as 50, and the relatively low fracture frequency, P_{10}, was from 9 to 11. The sizes of the DFNs ranged from 0.05 m to 0.5 m. The combination of these parameters results in the poorly cleated coal seam as nonpersistent discontinuities in the wide pillar gateroads system.

Contrastingly, the Fisher constant, K, was determined as 100, and the relatively high fracture frequency, P_{10}, ranged from 18 to 22 to generate the DFNs representing the subhorizontal included angles. The sizes of the DFNs ranged from 0.1 m to 1.0 m.

The resulting profiles of the vertical displacement across the surface of each floor of the gateroads are shown in Fig. 2. The solid-triangle curve indicates the displacements measured at the gateroads with the wide pillars. The dotted-circle curve presents the displacements obtained at the gateroads with the narrow pillars. The profiles of the vertical displacement across the surface of the floor of the gateroads in the wide pillars indicate that the maximum vertical displacement is as large as approximately 1 m with a convex-shaped curve, while the maximum vertical displacement of the floor is about 20 cm with a relatively flat curve with the narrow pillars.

Fig. 1 Floor heave observed in the underground coal mine.

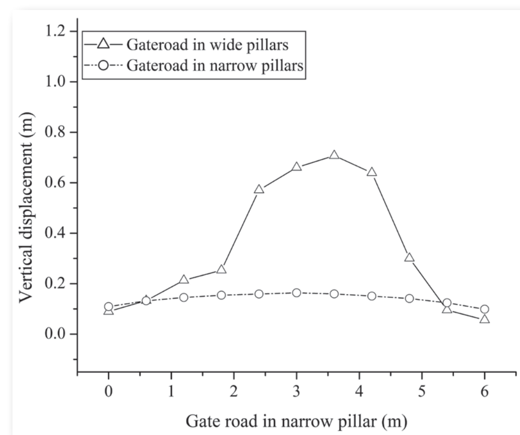

Fig. 2 Profiles of vertical displacement across the gateroad floor measured in the 3DEC model.

Conclusion

The 3DEC modeling in conjunction with the DFN technique was performed to better understand the true behavior of a floor heave associated with underground mining in the anisotropic stress field. The effect of stress rotation in the mining-induced stress field was considered by using different means of DFN orientation distribution in the coal seam. The wide pillar system had an oblique included angle that was generated by the DFN with a higher variability of the orientations. The narrow pillar system had a normal included angle that was generated by the DFN with a lower variability of the orientations. The DFNs explicitly simulated poorly cleated and well-cleated coal seams, indicating the different spacing between cleat apertures using the probability distribution functions on fracture density (or frequency) and size.

In summary, we have presented the DFN technique for implementing models having different anisotropic characteristics in the floor and coal of the narrow pillar region and the wide pillar region. The results of the numerical modeling matched observations of the relative amounts of heave from each gateroad system.

Disclaimer

The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the National Institute for Occupational Safety and Health. Mention of any company or product does not constitute endorsement by NIOSH. ■

Selected references

1. Itasca Consulting Group, Inc. (2019) 3DEC distinct element modeling of jointed and blocky material in 3D. User's guide, version 7.0
2. Kim B-H, Larson MK (2019). Numerical investigation of factors involved in a floor heave mechanism in a bump-prone coal mine. Proceedings of the 38th International Conference on Ground Control in Mining. Morgantown, WV, July 23–25, 2019. Society for Mining, Metallurgy & Exploration Inc. (SME), Englewood, CO