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Research Article

Experimental Investigation of Airflow Behavior in a Block Cave Mine

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Abstract

This paper discusses the airflow behavior in block cave mines. For this study we utilized a 1:100 scaled experimental model to investigate airflow characteristics under various cave porosity conditions, parallel fan conditions, regulated airflow systems, and changing undercut structures. Our observations from this study provide useful information to design an efficient and effective ventilation systems for block cave mines.

Introduction

Block caving is a favorable underground mining method for low-grade, deep seated, and massive ore deposits due to its high productivity and low operation cost. However, the extraction of gas-bearing ore deposits via drawpoints would result in harmful gas emissions into the production level. Maintaining a negative pressure on the cave through multiple fans and regulators is considered an effective way to deal with gas emission issues [1, 2]. Cave airflow behavior is highly dependent on cave structures (undercut level, air gap, orepass), cave parameters (caved material properties and footprint), and other elements (fan operation and regulator installation) [3-5]. It is not easy to investigate the cave characteristics under these conditions due to the dynamic caving process at a real operating mine. Therefore, this study developed a 1:100 experimental model to investigate the effects of caved materials, additional fan operation, regulators, and changing undercut structure on cave airflow behavior.

Materials and Methods

As shown in Figure 1, our scaled block cave model consists of a production level, an undercut level, drawbells, a caved zone, multiple fans, and regulators. The production level has nine production drifts inlets and outlets and 188 drawpoints with an El Teniente layout. Ninety-four drawbells are constructed to connect the caved zone and the production level. The caved zone is filled with different cubic cardboard boxes to investigate the effect of cave porosity conditions on cave airflow behavior. Three material cases are achieved by varying bottom region: three layers of 10cm boxes (Case 1), two layers of 15cm boxes (Case 2), and a mixture of both (Case 3); while the upper two regions are the same: two layers of 13cm boxes and one layer of 18cm boxes. Case 1 has a lower porosity than Case 3, even though they have the same height. In this study, a total of four scenarios are investigated. Scenario 1 has an exhaust fan connected to the cave top, while production outlets are closed; Scenario 2 is under parallel fan conditions: a top fan connected with the caved zone, and a bottom fan with production outlets, the bottom fan is operated under three conditions (fully open, half open, and closed); Scenario 3 is under a regulated airflow system, it has four combinations based on up and down regulators opening percentages (C 1: 100%+100%; C 2: 100%+50%; C 3: 25%+100%; C 4: 6.25%+ 100%); and in Scenario 4, production drift inlets are partly closed with nine regulators, two 15cm undercut drifts inlets are arranged under three conditions: no, small, and large gaps. As shown in Figure 1, our measurement point is located at Point A. All the experiments were conducted under the exhausted ventilation system, we did not observe any expansion of flexible sheets (used to cover the cardboard box bundles) and any movement of boxes within the caved zone.

Figure 1: Experimental setups: (a) inlets for scenarios 1, 2, and 3; (b) scenario 1; (c) scenario 2; (d) scenario 3; (e) inlets for scenario 4; (f) scenario 4.

Results and Discussion

As shown in Figure 2, P refers to the static pressure difference between the atmosphere and the point of interest, Q refers to the airflow rate through the duct; the slope of a P-Q curve represents cave airflow resistance. Figure 2(a) displays the effect of various materials on cave airflow resistance. Case 1 shows the highest cave airflow resistance compared to other material cases. During the experiment, it was observed that the middle drift has the highest airflow rate among nine production drifts since it connects with the largest number of drawpoints offering the least airflow resistance under a given fan condition. Figure 2(b) presents the impact of bottom fan conditions on cave airflow resistance under Case 2. The increase in bottom fan power escalates the cave airflow resistance and makes it more difficult to propagate through the caved zone. The additional fan operation can elevate the total airflow rate through the system. Figure 2(c) exhibits the effect of regulator installation on cave airflow resistance under Case 3. The regulator at either location increases the cave airflow resistance. Regulators used to distribute the airflow system (through the caved zone and production drifts), but they cannot increase the total air volume flow rate (Q) in the system. Figure 2(d) shows the impact of changing undercut structure on the cave airflow resistance under Case 1. From the P-Q plots, it can be observed that the increment in the gap dimension decreases the airflow through production drifts and reduces the cave airflow resistance as a result the airflow through the cave increases. These gaps are caused by poor rock fragmentation and can be observed in undercut drifts in an operating block cave mine.

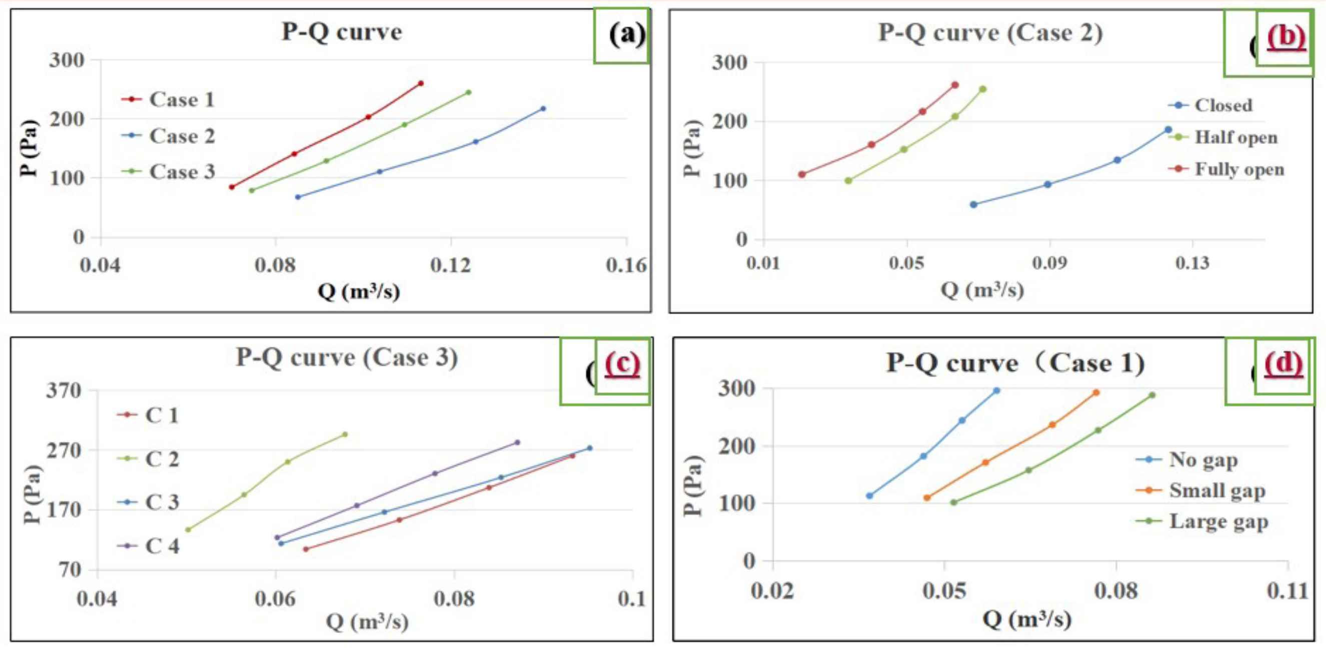

Figure 2: Cave characteristic curves (P-Q curves): (a) three material cases, (b) three bottom fan operation conditions, (c) four regulator combinations, and (d) three undercut gaps.

Conclusion

From this study, it was observed that the cave airflow resistance increases with a decrease in porosity and particle size, additional fan operation, regulator installation, and gap reduction in the undercut drifts. An additional fan operation can contribute extra total airflow through the system, but regulators will not increase the total airflow in the system; the gap observed in the undercut drifts might lead to less airflow through the production drifts. In block cave mines, both airflow rate and air pressure should be monitored as they reflect the changes occurring in the system in terms of rock properties (rock size distribution), changing cave structure, fan operation, and regulator installation conditions.

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