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Cap rock blast caving of cavity under open pit bench

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Abstract: A laser technique based scanning system was employed to make a comprehensive scanning through borehole for unmapped cavity under open pit bench, then the three-dimensional data will be obtained, and these data were used for theoretical analysis and numerical simulation to analyze the stability of cap rock. Acoustic emission techniques were also adopted to carry out long term real time rupture monitoring in cap rock. Therefore, a complete safety evaluation system for the cap rock was established to ensure safe operation of subsequent blasting processes. The ideal way of eliminating collapse hazard of such cavity is cap rock caving through deep-hole blasting, thus, two deep-hole blasting schemes named as vertical deep-hole blasting scheme and one-time raise driving integrated with deep-hole bench blasting scheme were proposed. The vertical deep-hole blasting scheme has more explosive consumption, but the relatively simple blasting net work structure can greatly reduce workloads. However, the one-time raise driving integrated with deep-hole bench blasting scheme can obviously reduce explosive consumption, but the higher technical requirements on drilling, explosive charging and blasting network will increase workloads.

Key words: open pit mining; cavity; laser 3D detection; cap rock stability evaluation; one-time raise driving; deep-hole blasting

1 Introduction

The cavity is one of the ongoing safety problems in mines resulting in surface subsidence and roof collapses in an operating area, especially in the area where cavities are unidentified, abandoned and unmapped, and has become a serious safety hazard. We know that these cavities exist in the mined-out areas left by underground mining operations. However, some of the open pits in China have also suffered terrible tragedies resulting from underground inaccessible cavities. These cavities are unfilled and inherited from previous underground mining, and are always unmapped (hidden under the working pit), making the situation even more complicated. This is mainly caused by uncontrolled mine planning and disorderly exploitation over the past several decades. These hidden dangers can severely restrict further exploitation and threaten the safety of personnel and equipment.

It is clear that initial accurate detection and mapping of cavities under open-pit benches are vital to address safety. Currently, 3D laser scanning using a pulsed, infra-red laser, to measure the “time-of-flight” of the laser pulse to calculate distance measurements, is a means for highly accurate modeling of cavities. This laser scanning is not affected by the geology around the cavity and obtains a very clear visual 3D model of its size, shape and orientation in a very short time [1]. After the cavity has been accurately mapped, the crucial problem is to evaluate the stability of the cap rock over it based on the detailed information, and this evaluation can be established through theoretical and numerical stress status analysis, and acoustic emission monitoring in cap rock [2−6]. As the safe operation of personnel and equipment above cap rock was finally confirmed, a reasonable cavity disposal approach should be proposed.

Usually, four ways can be adopted to dispose the abandoned stope, caving, filling, support and isolation [7], because all operation works for cavities under open-pit benches should be carried out on the surface rather than from underground, the eligible ways of disposing such cavities under open pit benches are caving and filling. However, the on-site application of crushed stone backfilling through large diameter borehole shows that stope backfilling will not only

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greatly increase the processing costs, but affect the subsequent grade of the mining ore. Therefore, the caving method has become the initial approach to deal with such cavities. There have been many engineering researches on the caving method for underground cavity disposal. The local grooving top-caving method was adopted by LI et al [7], bench blasting by LI [8], and deep-hole blasting by YE et al [9]. Depending on the actual situation of the cavities under open-pit benches, the caving scheme should be well planned for specific engineering applications, and the data obtained from 3D laser scanning have become a necessity for detailed processing formulation of the blasting, especially for those large cavities.

The integral processing scheme which includes accurate detection and cap rock stability evaluation of a large cavity under Sandaozhuang open pit bench of the Luoyang Luanchuan Molybdenum Group Inc., China, was discussed in this work, and two types of blast caving methods were proposed and compared based on the detailed 3D laser scanned data. These proposed the stability evaluation system and blast caving methods were learnt from peer and long-term experience accumulated at the Sandaozhuang open pit. In many one-time raise driving tests, we found that the blasting results and the on-site situation encountered are very different even the designed parameters are the same and the blasting operation is located in the same area on a bench, so the need for field experience on the impact of blasting is self-evident. Thus, the parameter design in this work is not necessarily universal; however, the topics in this work can provide a good disposal pattern for such separately existed cavities, and will be a valuable reference for other similar mines.

2 Cavity detection and cap rock stability evaluation

2.1 Detailed information of cavity

A typical open pit named the Sandaozhuang Mine run by Luoyang Luanchuan Molybdenum Co., Ltd., came from an underground mine. The Sandaozhuang Mine has experienced at least 20 years of uncontrolled underground mining since the 1980s, and was totally transformed into an open-pit mine in 2003. Massive cavities were left by sublevel open-stope mining and a large number of un-cleared cavities were left by private mining. As bench blasting proceeds, the cap rock becomes thinner, and workers and equipments on benches, in which considerable labor and resources have been invested, are directly threatened by underground cavities. These cavities greatly compromise safe mine production, and addressing the safety problems of cavities is the most important task in the whole process of open-pit mining.

The large cavity under bench 1438 is chosen for analysis and handling in this study. The rock mass around the cavity is mainly skarn and wollastonite with small structural belts or magmatic rocks, and the Protodyakonov coefficient of the rock mass varies from 12 to 16. The laser scanned data are edited in Cavity-Scan processing software and a 3D modeling package, to form an oriented, geo-referenced “point cloud” (Fig. 1), which can be exported into Surpac and Computer Aided Design (CAD) software. The projected ichnography of the cavity is of particular use on-site. The data can be transformed into exploitation ichnography in CAD to outline the cavity boundary as shown in Fig. 2. We can also calculate the roof and floor elevation of any point in the projected ichnography to output cross sections by processing the scanned data. As seen in Fig. 2, the roof

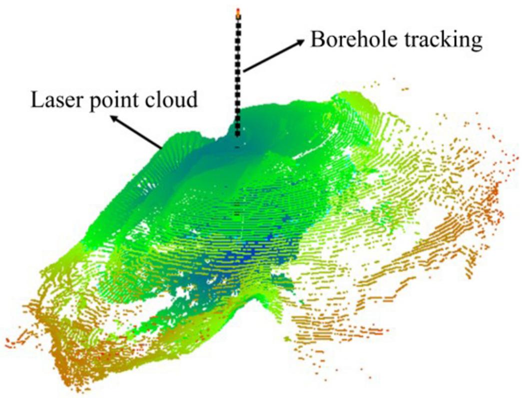

Fig. 1 Detected laser 3D point cloud of cavity under bench 1438

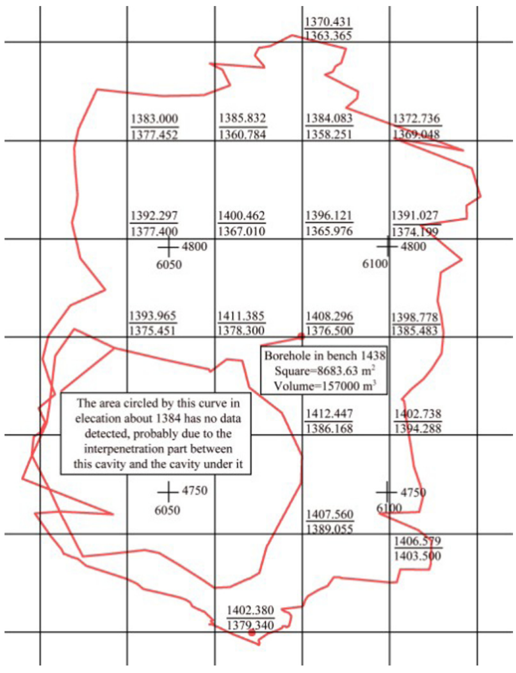

Fig. 2 Cavity ichnography with roof and floor elevation of grid intersection point (unit: m)

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