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Application of Coal Mine Roof Rating (CMRR) in Chinese coal mines

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ABSTRACT

The Coal Mine Roof Rating (CMRR) is a measure of roof quality or structure competency for bedded roof types typically of underground coal mines. The CMRR has been used widely in the US, South Africa, Canada and Australia. In order to investigate the application of the CMRR system in Chinese coal mines, two coal mines in China located in Panjiang Coal Field in Guizhou Province were investigated. Field data required to calculate the CMRR based on underground exposure were collected. The CMRR values of 11 locations in two coal mines were calculated. The investigations demonstrated that the chance of mine roof failure is very low if the CMRR value is more than 50, given adequate support is installed in mine. It was found that the CMRR guideline are useful to preliminary investigate stability in Panjiang Coal Field mines.

1. Introduction

Roof falls continue to be one of the greatest hazards faced by underground coal miners [1–3] especially in Chinese coal mines. Even though an individual roof fall accident could cause less injuries or fatalities than gas explosion, the total fatalities or damage to facilities caused by roof falls are more than the other type of mine accidents [4–7]. According to the data from the website of Minerals Council of Australia, China accounted for 51.2% of global black coal production in 2012, however, the fatalities caused by Chinese coal mines is three times the total of all the other countries in the world [4]. Furthermore, In 2012, in total there were 366 roof falls caused 459 fatalities in China, respectively accounted for 47% of the total accidents and 33.2% of the total fatalities [5].

Roof falls have been proved significantly difficulty to predict. One of the main reason is complex geology and soft rock formations may exist in underground coal mines [8–10]. Firstly, the structural competence of coal mine roof is greatly affected by natural weaknesses including bedding planes, fractures and small faults. Secondly, the engineering properties of rock cannot be specified in advance with adequate precision because it varies widely from mine to mine and even within individual coal mine. Also, engineers require quantitative data on the strength of rock masses for design. However, traditional geologic reports only contain few valuable descriptive information regarding engineering properties. In addition, laboratory tests, on the other hand, are inadequate because the strength of a small sample is only indirectly related to the strength of the rock mass [1].

To address this problem, rock mass classification systems can be implemented to quickly and reliably estimate the stability and support requirement of underground mines [11]. The Coal Mine Roof Rating (CMRR) is a classification system developed to investigate stability of underground mines. Recently, the system has been improved and modified [12]. In this paper, application of this system in assessing the stability of two coal mines in China was investigated.

2. The CMRR classification system

The CMRR is a measure of roof quality or structural competency for bedded roof types typical of underground coal mines, which was developed by the US Bureau of Mines in 1994 to fill in the gap between geologic characterization and engineering design [3,8,9,13]. It was derived from the South African Council for Scientific and Industrial Research's Rock Mass Rating (RMR) system, then it has been used in the mining and tunneling industries for over 30 years [13–15]. The CMRR is like a tremendous knowledge database of an intelligent decision support system (IDSS) so that an unskilled engineer can utilize the parameter in mine design and production management to improve coal mine roof support and its safety situation.

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The CMRR was initially developed based on field observations at surface highwalls and portals as well as underground air crossings and roof falls [8,9,16]. Later, it is followed by a methodology developed for assessing the CMRR from drilling core to deal with limited underground exposures [8,9,17].

The calculation of the CMRR either from underground exposures or from drilling cores has been greatly simplified by the development of a CMRR computer program [8]. Hill [13] suggests the following categorization of roof competency:

CMRR < 45 Weak roof
CMRR = 45–65 Moderate roof
CMRR > 65 Strong roof.

A study shows that 75% of the data fell into the "weak" or "moderate" categories with an average rating around 53 [13]. By contrast, Australian coal industry research in the late 1990s indicated a lower average rating for longwall mines of 50, with 86% of the data falling into the "weak" or "moderate" categories [13,18,19].

Because of the successful application of the CMRR in coal mine design and production, the safety situation and environment of coal mines have been greatly improved. This can be shown from the statistics of coal mine accident during recent five years or even longer. Especially, the fatalities decreased significantly. According to Molinda et al. [3], there were 790 injuries and 13 fatalities due to roof falls in 1998. For this reason a number of the National Institute for Occupational Safety and Health ground control research studies have concentrated on this area. Then the CMRR was widely used for a variety of purposes including roof hazard assessment, chain pillar design and stress modeling. Thus, the overall safety in American coal mines has improved dramatically. According to Harris et al. [4], during the period from 2006 to 2010, there were only 26 fatalities from strata fall in underground coal mines in the US.

The CMRR system has extensive application in the US, South Africa, Canada and Australia [1,10]. Worldwide experience has shown that the CMRR is a reliable, meaningful and repeatable measure of roof quality and stability. However, so far, there has been very limited application for this method in Chinese coal mines. In this study, stability condition of two coal mines in Panjiang coal field in Guizhou, China has been considered to investigate the application of the CMRR.

3. Application of the CMRR in Chinese coal mines

The suitability of the CMRR categorization of roof competency in Panjiang coal field is analyzed based on a series of data collected from underground exposures. Panjiang coal field is a rich coal reserves with proved reserves of 9.5 billion tons in area of 706 km^2. It is one of the main coal fields in western China. Shanjiaoshu coal mine and Laowuji coal mine are the two main mines located in Panjiang coal field. Thus, application of the CMRR is investigated in these two coal mines.

3.1. The studied coal mines

3.1.1. Laowuji coal mine

Laowuji coal mine is one of the six coal mines which belong to Panjiang Coal and Electricity Corporation located in the Panjiang coal field, nearby the south bank of the Tuochang River. Coal seams No. 3, No. 4, No. 10, No. 12, No. 14, No. 18, No. 22 and No. 24 are the minable coal seams having depths ranging between 0 to 550 m. The thickness of minable coal seams varies from 0.7 m to 26.98 m. The average total thickness of all minable coal seams is 12.94 m. The mine started to become productive in 1975. By 2015, its coal production had been 1.15 million tons per year.

Coal seam No. 12 is the major minable coal seam which its thickness varies from 1.19 m to 8.05 m. The depth of cover ranges from 50 m to 500 m across the reserve area. The case studies comprised of five locations within roadways of coal seam No. 12 east second panel. These roadways were irregular; rectangular in section with 4.6 m wide, 2.6 m height on the left side and 3.6 m height on the right side. Φ20–2500 screw steel bolts having spacing of 0.8 m in both row and line, supplemented by 8.3 m anchor cable having row spacing of 2.4 m and line spacing of 1.6 m support these roadways. Table 1 shows the information of the coal mine.

3.1.2. Shanjiaoshu coal mine

Shanjiaoshu coal mine is another large mine in the area which is located between Laowuji coal mine and Yueliangtian coal mine. Coal seams No. 10, No. 12, No. 15, No. 17, No. 18, No. 18-1, No. 19 and No. 20 are the minable coal seams in the mine and vary from 0 m to 580 m in depth. The thickness of minable coal seams varies from 2.88 m to 30.15 m. The average thickness of all minable coal seams is 15.48 m. The mine started to become productive in 1974 with 1.5 million tons per year production in 2015.

Coal seam No. 10 is the major minable coal seam which its thickness varies from 0.30 m to 2.58 m. The depth of cover varies from 50 m to 580 m across the reserve area. The case studies comprised of six locations within roadways of coal seam No. 10 west second panel. These roadways were semi-circular arch in section with 5 m wide, 1.3 m wall height and 1.7 m arch height. M20-2470 bolts having row and line spacing of 0.7 m supplemented by 6 m anchor cable with row spacing of 2.1 m and line spacing of 0.7 m support these underground openings. Table 2 demonstrates the information.

3.2. Data collection

Fig. 1 [1,2,8] demonstrates data collection procedure being implemented to gather and organize data from these two coal mines. The information is collected by mine engineers from roof exposures and roof falls.

3.3. Calculation of the CMRR

Calculation of the CMRR values was undertaken using the CMRR software obtained from the website of the National Institute of Occupational Safety and Health (NIOSH).

Fig. 2 shows example of the results being analyzed by the software from location 1: 121215 tailgate, Laowuji coal mine. Tables 3 and 4 show the CMRR values being calculated for Laowuji coal mine and Shanjiaoshu coal mine respectively.

From Tables 3 and 4, it can be seen that the rating of CMRR varies from 50 to 65. Based on Hill [13], if CMRR = 45–65, the roof rating is moderate. Therefore, a conclusion can be drawn that the roof of Panjiang coal field is a moderate roof.

3.4. Comparison between the CMRR rating with roof stability condition

Molinda et al. [3], through an empirical study on 37 coal mines in the US, showed that roof rock strength measured by the CMRR is the parameter which is the most closely related to the roof fall rate. The relationship between roof fall rate and the CMRR rating shows that most of the moderate to high roof fall rates are likely to happen when CMRR $\leq$ 50. All the cases of CMRR $\leq$ 30 show moderate to high roof fall rates. However, high roof fall rates are rare for cases of CMRR $\geq$ 60.

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