International Journal of Mining Science and Technology 27 (2017) 853–860

Contents lists available at ScienceDirect

International Journal of Mining Science and Technology

journal homepage: www.elsevier.com/locate/ijmst

Hydraulic support crushed mechanism for the shallow seam mining face under the roadway pillars of room mining goaf

Wang Fangtian [a,b,*], Duan Chaohua [c], Tu Shihao [a,b], Liang Ningning [a,b], Bai Qingsheng [a,b]

[a] State Key Laboratory of Coal Resources and Mine Safety, China University of Mining & Technology, Xuzhou 221116, China
[b] School of Mines, Key Laboratory of Deep Coal Resource Mining, Ministry of Education of China, China University of Mining & Technology, Xuzhou 221116, China
[c] School of Economics and Management, Longyan University, Longyan 364000, China

ARTICLE INFO

Article history:
Received 12 January 2017
Received in revised form 18 March 2017
Accepted 15 May 2017
Available online 18 August 2017

Keywords:
Shallow seam
Room mining goaf
Longwall mining
Hydraulic support crushed mechanism
Safe and efficient mining

ABSTRACT

While the fully-mechanized longwall mining technology was employed in a shallow seam under a room mining goaf and overlained by thin bedrock and thick loose sands, the roadway pillars in the abandoned room mining goaf were in a stress-concentrated state, which may cause abnormal roof weighting, violent ground pressure behaviours, even roof fall and hydraulic support crushed (HSC) accidents. In this case, longwall mining safety and efficiency were seriously challenged. Based on the HSC accidents occurred during the longwall mining of 3-1-2 seam, which locates under the intersection zone of roadway pillars in the room mining goaf of 3-1-1 seam, this paper employed ground rock mechanics to analyse the overlying strata structure movement rules and presented the main influence factors and determination methods for the hydraulic support working resistance. The FLAC3D software was used to simulate the overlying strata stress and plastic zone distribution characteristics. Field observation was implemented to contrastively analyse the hydraulic support working resistance distribution rules under the roadway pillars in strike direction, normal room mining goaf, roadway pillars in dip direction and intersection zone of roadway pillars. The results indicate that the key strata break along with rotations and reactions of the coal pillars deliver a larger concentrated load to the hydraulic support under intersection zone of roadway pillars than other conditions. The "overburden strata-key strata-roadway pillars-immediate roof" integrated load has exceeded the yield load that leads to HSC accidents. Findings in HSC mechanism provide a reasonable basis for shallow seam mining, and have important significance for the implementation of safe and efficient mining.

1. Introduction

Shallow coal seam is characterized by shallow buried depth (less than 100–150 m depth), overlain with thin bedrock (no more than 50 m thick) and thick loose sands. The longwall mining under these conditions is likely to cause whole overburden strata collapse, roof step subsidence or hydraulic crushed accidents [1,2]. Prior to the large-scale longwall mining in the Shendong Coalfield in 1990s, room mining and knife-pillar mining methods were commonly used to support the roof with room mining pillars and roadway pillars. It causes the high ground stress concentration while the close seam mining face advanced to these pillars below, such as rapid growth of working resistance, substantially shrinking of hydraulic support pistons, and incessantly unlocking of safety valves, and even HSC accidents. Therefore, the study of HSC mechanism for the longwall mining under the roadway pillars of room mining goaf is of significance for a safe and efficient mining in Shendong Coalfield.

Scholars have carried out numerous researches focusing on ground pressure rules in shallow seams mining, instability mechanism of residual pillars in the room mining goaf, and the safe and efficient mining of the close seam below the goaf. Holla and Buizen indicated that roofs of shallow coal seams intend to fall along the longwall mining goaf like a "bottle cork" and caved roof height was about 9 times of mining height. Support resistance rises significantly during roof breakage, leading to intensed pressure and control difficulty [3]. Focusing on drastic strata behaviours in Sohagpur Coalfield while periodic weight distance of longwall mining comes into being, Banerjee et al. provided some techniques like long-hole blasting and hydraulic fracture to reduce the cost of the hydraulic support resistance improvement, thence ground drill blasting on corresponding goaf was applied to prevent HSC acci-

* Corresponding author at: State Key Laboratory of Coal Resources and Mine Safety, China University of Mining & Technology, Xuzhou 221116, China.

E-mail address: wangfangtian111@163.com (F. Wang).

http://dx.doi.org/10.1016/j.ijmst.2017.07.013
2095-2686/

dents [4]. Maleki enhanced the understanding that the horizontal stresses build up and release during coal pillar loading and unloading in bump-prone U.S. mines [5]. To provide far more robust design outcomes of the coal pillar, Reed et al. considered the independent influences of pillar w/h ratio, overburden W/H ratio and the presence of thick, massive strata units within the overburden in conjunction with pillar factor of safety [6]. Huang et al. constructed models of "short block structure of voussoir beam" and "step voussoir beam" during periodic weighting of roof in shallow seam, and developed computing formula of support resistance [7]. Hou proposed a discriminant function of step falling for total overburden rock and pointed out factors affecting strata behaviour of shallow seam, which included thickness of losses sands and bedrock, support resistance, mining height and immediate roof thickness [8]. Tu et al. carried out the study of rock burst tendency caused by mining rock elastic energy evolution [9,10]. The relationships between ground surface displacement and underground strata behaviour were figured out while the longwall working face under the shallow room mining goaf. Wang et al. presented the instability mechanism of the room mining residual coal pillars and revealed the deep-hole pre-split blasting for controlled roof caving mechanism, and the field application enabled the longwall mining safely and efficiently [11,12].

Based on the supports crushed accidents, and induced by the longwall mining of shallow seam under roadway pillars of room mining goaf in Shigetai Mine, the study investigated the overlying strata movement mechanism, the determination of reasonable hydraulic support load, and the ground stress distribution. It provides a scientific reference for the longwall mining of shallow seam under the roadway pillars of room mining goaf.

2. Engineering background

2.1. Geological conditions of working face

3-1-1 seam and 3-1-2 seam are the main minable coal seams with a distance of 0.2–13.4 m in Shigetai Mine of Shendong Coalfield. Average burial depth of 3-1-2 seam is 81.2 m in LW131205 with a 3.0 m mining height. The column diagram of roof and floor is shown in Fig. 1.

No.	Thickness (m)	Depth (m)	Lithology	Histogram	Remark
1	18.0	18.0	Wind-blown sand topsoil		Undulating relief
2	18.0	36.0	Fine sand and gravel		
3	13.8	49.8	Sand clay and fine sandstone		
4	0.7	50.5	2-1 coal seam		
5	0.9	51.4	Sand shale		
6	0.6	52.0	2-2 coal seam		
7	2.6	54.6	Sand shale		
8	0.4	55.0	Coal seam		Key strata
9	14.5	69.5	Sandstone		
10	2.7	72.2	3-1-1 coal seam		Room mining
11	6.0	78.2	Sand and fine sand mud interbed		Immediate roof
12	3.0	81.2	3-1-2 coal seam		Longwall mining
13	27.0	108.2	Sand and fine sand mud interbed		Seam floor

Fig. 1. Column diagram of roof and floor.

The inclined and strike lengths of LW131205 are 150 and 1400 m, respectively. The room mining goaf of 3-1-1 seam with a room-pillar space of 6 m × 6 m is above this face. In addition to a large number of residual room coal pillars, there also exist roadway pillars with a width range of 10–20 m. The applied hydraulic support type is ZY6800/17/35 with a yielding resistance of 6800 kN and its off-loading strength of safety valve is 40 MPa. The roof conditions of LW131205 are complicated with four types regions along advance direction: solid coal region, residual room mining pillar region, the crossing-over region of strike and inclined pillars, and the residual room mining pillars and strike pillars region.

The overlying conditions of LW131205 are illustrated in Fig. 2.

2.2. HSC accidents

HSC accidents occurred when LW131205 advanced to the crossing-over region of roadway pillars. Pillars distribution and location of crushed area are presented in Fig. 3.

When the working face advanced to the borderline of the coal pillars, the roof weighting was so intensely that the supports safety valve of Nos. 43-61 unlocked incessantly. The working resistance of hydraulic support was beyond 40 MPa on average and descending amount of supports piston reaches 1300 mm, and the coal wall spalling seriously at the same time. Specially, Nos. 46–56 hydraulic supports crushing accident occurred, which led to a 7 days halting production and following restricts of safe and efficient mining of LW131205.

3. HSC mechanism analysis

3.1. Stress superposition of roadway pillar in crossing-over region

Stress-concentrated zone is formed due to the re-distribution of overburden stress after room mining. Coal-rocks are undermined from coal wall inward in some depth under the influence of abutment stress and mining induced stress. As pillars go deeper, stress increases until it reaches maximum. As shown in Fig. 4, the distribution of abutment pressure on pillars and width of yield zone vary from pillar to pillar.

According to limit equilibrium theory, the width of yield zone on pillars' two sides can be calculated by Eq. (1).

$$Y = \frac{h}{2\xi f}\ln\frac{K\gamma H + C\cot\varphi}{\xi C\cot\varphi} \quad (1)$$

where Y is the width of yield zone; K the abutment stress coefficient; h and H the mining height and depth, respectively; r the specific gravity of surrounding rocks; C and φ the cohesion and internal friction of coal, respectively; f the friction factors of interface between seam and roof and floor; and ξ the triaxial stress coefficient, and $\xi = (1 + \sin\varphi)/(1 - \sin\varphi)$.

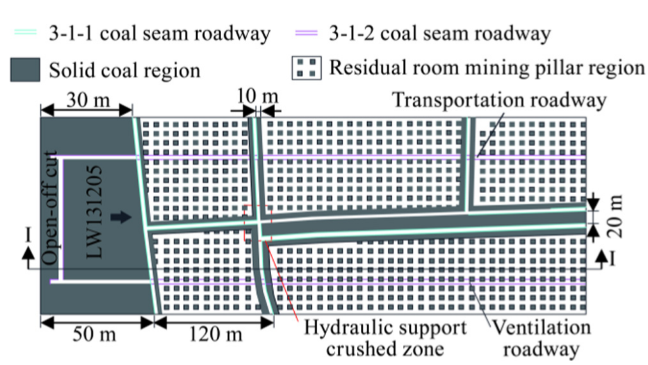

Fig. 2. Overlying conditions of LW131205.