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Layout and support technology of entry for pillar face

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ABSTRACT

In order to improve the recovery rate of coal, some mines have begun to recover the residual protective pillars in the form of short wall faces. However, it is difficult to control stability of the haulage entry and the ventilating entry under the mining influences of the pillar face and the two side faces. Thus the 4311 face, which was designed to recover the 57 m wide residual protective pillar in Guojiashan Coal Mine, was taken as engineering background. Distribution law of stress and plastic zone in the residual protective pillar was analyzed using the numerical simulation. Then the gob-side entry driving technology was proposed to layout the entries for the pillar face. Based on the analysis of stress distribution and deformation characteristics of surrounding rocks in gob-side entry driving with different width of narrow pillars, the width of the narrow pillar of the entries in the 4311 face was decided to be 4 m. In order to control stability of the gob-side entry driving, the mechanical model of the main roof was established and deformation characteristic of surrounding rock was analyzed. Then the bolt support technology with high strength and high pre-tightening force was proposed for entry support. Especially, the hydraulic expansion bolts were used to support the narrow pillar rib. The engineering results show that the width of the narrow pillar is reasonable and the entry support technology is effective. The research achievement can provide some references to pillar recovery for other coal mines.

1. Introduction

To prolong service life of mine and improve recovery rate of coal, some mines have begun to recover the residual protective pillars of the main entries, rise entries and dip entries [1,2]. The pillars, ranging from dozens of meters to over 100 m in width, usually are recovered in the form of short wall faces. However, because area on both sides of the pillar is gob (waste) and the width of pillar is less than that of conventional face, abutment pressure resulting from many mining influences in the pillar is high. This can lead to serious failures of surrounding rock and support in haulage entry and ventilating entry; furthermore, pillar face mining is unsafe. Therefore, reasonable layout and support technology of entry, reducing the influence of high abutment pressure on entries, is the key for pillar recovery.

Recently, several mines recovered some residual protective pillars, as described below. A mine in Wuhai city recovered the 180 m wide pillar which was the protective pillar of the dip entry in No. 5 coal seam. Thereinto, the gob-side entry driving technology was used to layout the haulage entry and ventilating entry, and the narrow pillar width of the entries was 2 m [3]. To be clear in this study, the residual protective pillar is called as large pillar; and the chain pillar of gob-side entry driving is named as narrow pillar; similarly hereinafter. Shaoxin Coal Mine recovered the 40 m wide large pillar, which was the protective pillar of +395 m main entry. The completely gob-side entry driving technology was used to layout the haulage entry and ventilating entry; the single hydraulic props and the filling piers were applied to entry support [4]. Bigezhuang Coal Mine adopted respectively T-shape and L-shape methods to recover the large pillars in Nos. 5 and 7 coal seam, which were the protective pillars of the concentration dip entry in No. 2 working district [5]. In order to safely recover the 100 m wide No. 43M1 pillar, Wangzhuang Coal Mine identified 17 m as the critical value of the chain pillar width through the study on surrounding rock stability of entry with the different chain pillar widths [6]. Ghasemi proposed a method involving calculating the large pillar recovery-risk (PR-Risk) indicator. PR-Risk value is between 0 and 100 based on overall risk of pillar recovery operation divided into four categories: low, medium, high, and very high [7]. As can be seen, the study on large pillar recovery is less, especially tens of meters wide large pillar.

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In addition, the gob-side entry driving technology was involved in this paper. The main research achievements about the technology are as follows. Hou and Li put forward stability principle of the large and small structures based on characteristics of rock surrounding gob-side entry driving [8,9]. Bai established the mechanics model of the arc-triangle key block structure in the main roof, and analyzed stability of the structure at different stages, more importantly, presented the viewpoint that the narrow pillar is an important component of the structure [10]. The gob-side entry driving technology was used in not only a conventional face but also an isolated face [11]. Wang et al. studied distribution law of the abutment pressure in 2107 isolated face in Changcun Coal Mine, and determined peak and decline area of abutment pressure; by successfully avoiding high abutment pressure zone, the narrow pillar width of entry of No. 2107 isolated face was identified as 5 m [12]. Zhang et al. showed that the maximum advance abutment pressure of the gob-side entry driving in 17,238 isolated face was 1.84 times as high as the conventional face in Huanan mining area [13]. Hua et al. concluded that: when advance abutment pressure of the isolated face increased obviously, surrounding rock deformation of gob-side entry driving in the isolated face increased dramatically, which added to difficulties in entry support; further, he proposed combining support using bolt, cable, wire mesh, and grouting to effectively control surrounding rock deformation of the gob-side entry driving in 1251(3) isolated face in Pansan Coal Mine [14]. Zhang et al. analyzed stress distribution and deformation features of the narrow pillar in the gob-side entry driving under the condition of unstable strata surrounding rock, and proposed trinity coupling support technology using the high strength bolt and grouting anchor to control stability of the narrow pillar [15]. From previous studies, it is clear that the applications of the gob-side entry driving technology were more on the conventional faces and the isolate mining faces, but less on large pillar recovery.

Therefore, the study takes the 57 m wide large pillar in Guojiashan Coal Mine, which was designed to be recovered by the 4311 face, as background. Based on distribution law of stress and plastic zone in the large pillar, the reasonable positions of the haulage entry and ventilating entry were determined and reliable support technology was developed, which guaranteed safety of 4311 face mining. Moreover, the study can improve economic benefit of Guojiashan Coal Mine and provide some references to pillar recovery for other coal mines.

2. Production and geologic condition of 4311 face

Guojiashan Coal Mine is mainly mining No. 4 coal seam which lies in the median-lower Taiyuan Formation. The coal seam is mainly of coking coal type, simple geological structure, stable horizon, average 4.0 m thickness, averaged 5° dip angle, average 1.5 Protodyakonov coefficient, about 180 m depth. The lithological characteristics of roof and floor are listed in Table 1.

Table 1
Roof and floor lithology of No. 4 coal seam.

Name		Thickness (m)	Protodyakonov coefficient	Lithology
Roof	Main roof	3.30	3.0	Gray black fine and medium sandstone, hard
	Immediate roof	1.12	1.0	Sandy mudstone, easily caving
	False roof	0.21	0.5	Black mudstone, easily breakable
Floor	Immediate floor	0.15	1.0	Black mudstone, easily breakable
	Main floor	5.40	3.0	Black fine sandstone, hard

In order to improve the recovery rate of coal, Guojiashan Coal Mine starts to recover some large pillars [16]. Among them, the 4311 face was designed to recover the large pillar which was 57 m in wide and 610 m in length in the northern of No. 1 working district. The eastern side of the 4311 face is three rise entries of No. 1 working district; the western side is oxidized zone and mine field boundary; the northern side is 4313 face; and the southern side is 4309 face (Fig. 1). The 4313 face and the 4309 face had been finished by 2004 year. The haulage entry and the ventilating entry were driven along seam floor by blasting, and their section was rectangular form with 3.8 m wide and 2.6 m high.

3. Layout technology of entry in pillar face

3.1. Distribution law of stress and plastic zone in large pillar

Compared with the conventional face mining, the large pillar has two noticeable production characteristics. Firstly, area on two sides of the large pillar is gob, known as the isolated pillar. Secondly, its width is smaller. The first characteristic can lead to the superimposition of lateral abutment pressure caused from two side face mining on the large pillar. The second characteristic will aggravate superimposition degree. To carry out a more comprehensive analysis of distribution law of stress and plastic zone in the large pillar, the numerical models with the large pillar width of 20, 30, 40, 50, 60, 70 and 80 m were built using FLAC3D software according to basic production and geological condition of the 4311 face in Guojiashan Coal Mine. Their dimensions were 400 m in width which was equal to width of the large pillar and two side gobs, 400 m in length which was equal to part of length of advanced distance of the pillar face, 52 m in height which was equal to part of thickness of surrounding rock. The upper boundary is loaded by weight of overlying strata, the bottom boundary is fixed in vertical direction, and the lateral boundary is fixed in horizontal direction, lateral pressure coefficient being 0.8. The mechanical parameters of coal and rock are shown in Table 2, and their stress dependence conforms to Mohr–Coulomb yielding criteria.

When the 4309 face was finished, the abutment pressure peak value in the large pillar is 14.10 MPa, that is to say, stress concentration factor is 3.1 (initial vertical stress is 4.5 MPa). Then when the 4313 face was also finished, superimposition of lateral abutment pressure caused from the 4309 face and 4313 face mining occurred in the large pillar, which leads to the increase of the abutment pressure peak value. In detail, when the width of the large pillar width is 50 m, the abutment pressure peak value is 14.5 MPa; and when the width of the large pillar is 20 m, the abutment pressure peak value is 20.8 MPa (the stress concentration factor is 4.6). It is clear that, with the decrease of the large pillar width, stress superposition degree increases gradually, and the abutment pressure peak value also increases (Table 3).

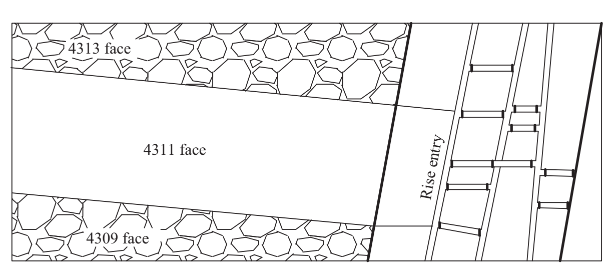

Fig. 1. Location diagram of 4311 pillar face.